Thesis/
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Supplement #51

A Classification of Surface Mine Spoils Hydrology, Surface Erosion, and Water Chemistry in Utah

Phase One Report

by

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Prepared for and Under
the Auspices of the
Intermountain Forest and Range
Experiment Station and the
SEAM Program, U.S. Forest
Service, United States Department
of Agriculture.

February 1, 1976

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Experiment Station, Ogden, Utah

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I

OVERVIEW OF THE PROJECT

Purpose and Objectives

The study of surface hydrology, erosion and water quality on mine spoils and tailings has application to on-site rehabilitation of lands disturbed by mining activity. This study lends itself to a better understanding of the possible impacts of sediment production rates and other water quality parameters on terrestrial and aquatic environments both on and off site.

Since little is known regarding hydrologic aspects of spoils and tailings in Utah, this study was initiated to gather facts on surface infiltration capacities, surface runoff and erosion on a variety of mine waste deposits in the state. Incorporated within this objective the study attempts to find a physical classification of spoils and tailings based on these surface characteristics.

If certain characteristics of mining spoils, recognized in one mining locality, are also found at another mining site, then will the surface hydrology and erosional characteristics of spoils at both sites be the same? A question similar to this one was asked by May and Striffler (1967) at the International Symposium on Forest Hydrology. If indeed a classification scheme can be obtained, this question will be answered for many mining areas and those "certain characteristics" that affect surface hydrology will be definable.

These first efforts to classify Utah mine spoils and tailings have involved the collection of surface hydrologic data and other appropriate characteristics for 24 mining localities that at present or in the past have mined 16 different mineral commodities from deposits located all over the state.

Methods of Site Characterization

A site* in this report is considered to be a specific spoils deposit or part of a deposit sampled in the study, therefore a mining locality is sometimes represented by several sites.

Selection of study sites: In selecting sites for this project, all district offices of the Bureau of Land Management and all U.S. Forest Supervisor Offices in the state were contacted to find out which mining areas might be best suited for the study. Two weeks were spent in the field with personnel representing these agencies to view the areas before making final selections. All types of mining activity were considered initially as possible sampling areas.

The principal types of mining included in the final site selections were: gold, silver, lead, zinc, fire clay, brick clay, limestone, flourospar, phosphate, coal, copper, tungsten, uranium, vanadium, and beryllium.

Site attributes: Within the 24 mining localities chosen for analysis, 35 sites are represented, 26 of which are spoils or mined over burden wastes, 7 are tailings, and 2 are ash deposits.

Attributes which are considered to effect the physical characteristics of materials in the surface of the waste deposits were studied at each site. Those include: elevation, aspect, slope, mean annual rainfall, geologic derivation of the spoils, manipulation, treatments, and disposal effects, bulk density, texture, percent of grains larger than 2 mm in diameter, and spoil salinity and pH.

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*Site is used here in lieu of the term plot since samples were taken from a number of infiltrometer plots on each spoils pile (or tailings pile).

Other descriptive characteristics obtained were: location, district name, type of mining, hand-speciman identification of petrologic types, land area occupied by the site, slope lengths, vegetation zone, and past mining history.

Special characteristics such as stratification in tailings ponds, regrading and revegetation of spoils, and surface concentrations of windblown deposits may have a profound influence on surface hydrology and were included in the description of sites, wherever appropriate.

Methods of Data Collection

The following sub-sections discuss the methods used to obtain data relating to the surface hydrology of Utah spoils and tailings.

Analysis of surface materials in spoils and tailings: For a given site, four to eight samples of the spoils or tailings materials were collected from the top ten centimeters of the surface and then mixed. The composite samples were later sent to the Soil, Plant and Water Analysis Laboratory at Utah State University for determination of a number of chemical, physical, and fertility characteristics. Those characteristics included pH, salinity (mmhos/cm), phosphorous (ppm), organic carbon (%), water soluble sodium (me/100 g), sulfate (me/100 g), estimated texture, percent grains larger than 2 mm diameter, and percent moisture by weight at saturation.

Surface hydrology and erosion: For estimating parameters of infiltration, surface runoff, and potential sediment production, a rainfall simulator or infiltrometer, as it is called, was used to collect four samples of each parameter at each site. The infiltrometer (figure 1) was patterned

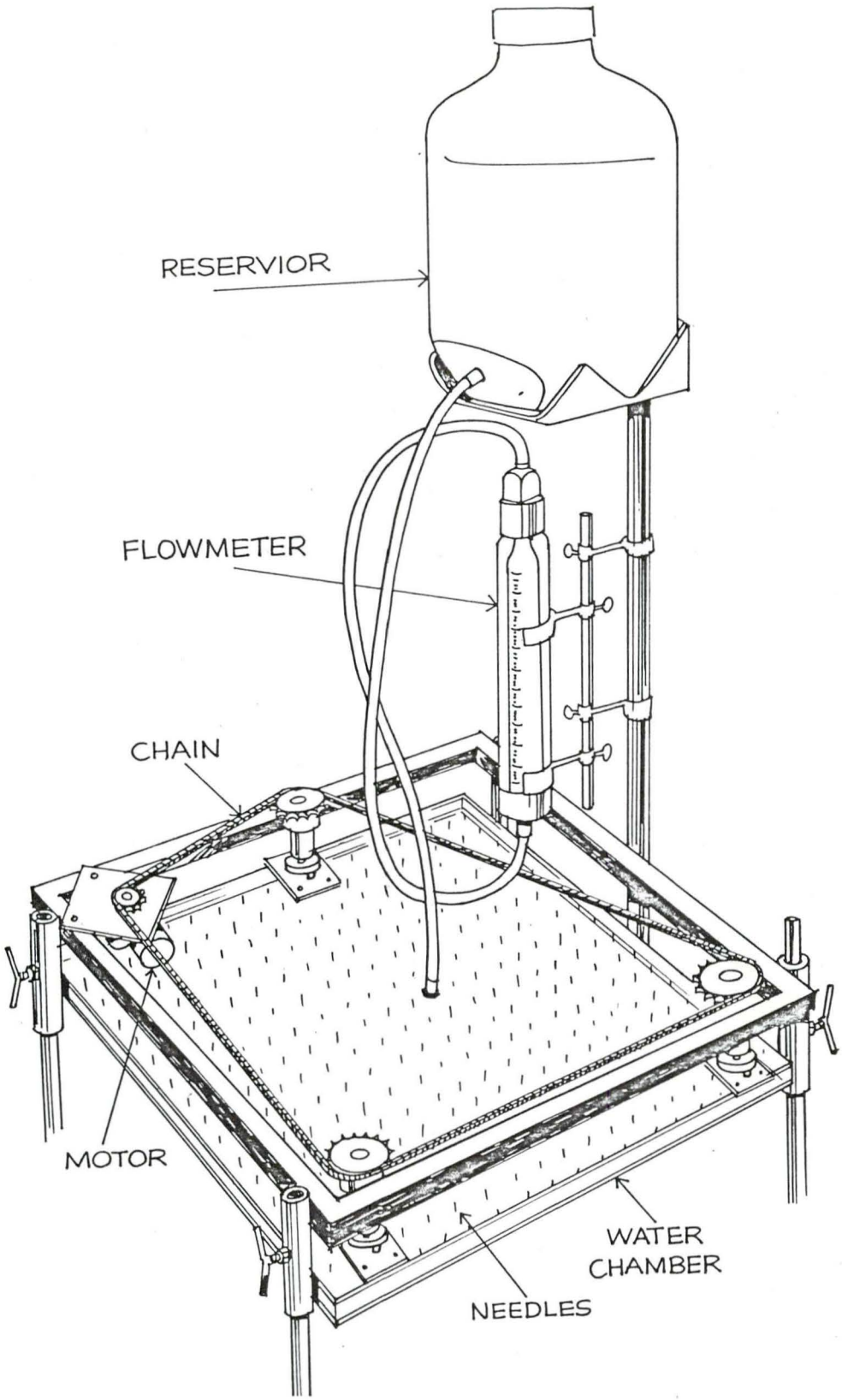


Figure 1. Infiltrometer used for determining infiltration rates, potential sediment production rates, and chemical water quality characteristics of surface runoff on mine spoils and tailings in Utah.

after one used by Meeuwig (1971) in studies of granitic soils in California. The infiltrometer used here was designed especially for use on steep slopes with bare soils and is therefore well suited for mine spoils studies. The infiltrometer was described by Aliakbar Malekuti (1975) in the first study that utilized this particular model. His description follows:

1. Water chamber: 60.92 cm by 60.92 cm by 2.54 cm (2 ft. x 2 ft. x 1 inch) plexiglass box.

2. Flow meter: regulates flow from the reservoir to the chamber and therefore the rate of rainfall.

3. Reservoir: 5 gallon polyethylene container connected to the flow meter by flexible plastic tubing.

4. Electric motor: powered by a six volt battery to rotate the chamber (used to distribute raindrop positions).

5. Hypodermic needles: 517 stainless steel tubes with a .476 mm (.0188 in.) inner tube diameter and a .635 mm (.025 in.) outer diameter. The tubes project 3.175 mm (1/8 inch) above and 9.525 mm (3/8 in.) below the plexiglass base of the chamber.

The infiltrometer was calibrated to produce rain falling at an intensity of 7.6 cm/hour (3 in/hr) over a plot size of 3,413 cm^2. The rainfall intensity varies, however, with slope of the plot since plot size increases to 5,075 cm^2 on a 100% slope. Sampled slopes produced a range of rainfall intensities that varied between 6.5 cm/hour on steep slopes to 7.6 cm/hr on gentle slopes. Each sample was represented by a 28 minute duration of the rain falling at a constant rate. The machine produces raindrops with a diameter of .25 cm that fall through an average verticle distance of 91 cm.

Drop size and terminal velocity can be calculated from two equations given by Chow and Harbough (1965).

$$d = 2.4\ (\gamma d_t)^{1/3}$$

where:

d_t = inner tube diameter (inches)

γ = surface tension of water in contact with air = .005 lb/ft

d = drop size (inches)

Terminal velocity is calculated as follows.

$$V_t = \left(\frac{4 \gamma d^3}{3 \rho C_d d_i^2}\right)^{1/2}$$

where:

γ = the unit weight of water (62.4 lb/ft^3)

d_i = the diameter of a transformed hemisphere which is geometrically equal to 1.25 d

C_d = the drag coefficient

ρ = mass density of the air (.0024 lb sec^2/ft^4)

Drops produced by the machine have a terminal velocity of approximately 20.98 ft/sec. Drops are small enough so that the average final velocity of drops that fall only 91 cm is 13.86 ft/sec. This is about 66 percent of terminal volocity.

The water chamber is rotated in a horizontal position to insure that equal water pressure on the needles and drop distributions are such that rain falls at a uniform rate on random positions over the plot.

On the downslope position of the plot, a flume was constructed for delivering plot runoff to a bucket. The volume and rate of runoff was measured using a graduated cylinder and stopwatch. Infiltration was then calculated as the difference between rainfall and runoff.

Because of the rocky nature of most spoils materials, a plot frame could not be employed. A certain degree of error must therefore be attributed to splash loss and lateral movement of ground water away from the plot when calculating infiltration and runoff volumes and rates. Errors may also result from the low velocity of simulated raindrops which might not puddle the surface of bare spoils as would natural raindrops.

The collected runoff was agitated so as to suspend the sediment produced by the operation and thereafter sampled by placing a one-quart jar in the stirred mixture. The quart sample was later analyzed for electrical conductivity, pH, and salinity.

At each site, four or more samples of runoff were collected from selected plots located within reasonable access of the equipment. Each plot was separated by a distance approximately equal to one-fourth the lengthwise dimension of the site. The separation distance was paced off and a random number was selected to finally locate the plot at some additional distance of separation equal to the random number. Final plot locations, however, were sometimes affected by large rocks or other obstructions that prevented installment of the collecting flume. In such instances, the plot was moved so that the obstructions were located immediately adjacent to the collecting area.

Tests using the student t statistic showed that for many sites the mean of four samples is an adequate representation of surface hydrology, but only on a marginally-significant level. Tests on a higher level show a range of required sample sizes from 2 to 14 depending on the variability in infiltration capacities produced by the unique conditions associated with the various spoils or tailings deposits.

Sediment produced by the overland flow collected in this experiment can be analyzed in terms of the erodibility of the various spoils and tailings materials. Erodibility is primarily a function of soil detachment, which is defined as the removal of particles from their positions on the surface of the soil by the impact of falling raindrops (Rose, 1960) and soil transport, which is the process by which water carries detached particles away from their original positions on the soil surface (Young, 1972). This means that soil erosion is influenced greatly by storm characteristics and by the volume and velocity of runoff waters. Volume and velocity, in turn, are functions of the infiltration capacity and slope of the spoils. With these facts in mind, an analysis of surface hydrology and erosion is not complete if only direct runoff and sediment production rates are measured. A certain amount of information was therefore obtained for other factors that are believed to influence both infiltration and erosion on bare spoils. These factors include: soil texture and structure, compaction (bulk density), conditions of the sediment surface, percent slope, length of slope, percent of grains larger than 2 mm, and approximate percent of surface area covered by particles larger than 2 cm in diameter. Soil texture was estimated by the U.S.U. Soil, Plant and Water Analysis Laboratory and checked in the field. Bulk density was determined from ring samples taken in the field. Other factors were measured or observed in the field.

Quality of surface runoff: The water quality analysis of surface runoff waters included the determination of sediment concentration (grams/liter), total sediment produced by a test run (grams), pH, salinity (ppm), and electrical conductivity (MHOX1). Sediment concentrations were determined by evaporating the one-quart sample of water taken from the total runoff

UTAH MINING DISTRICTS

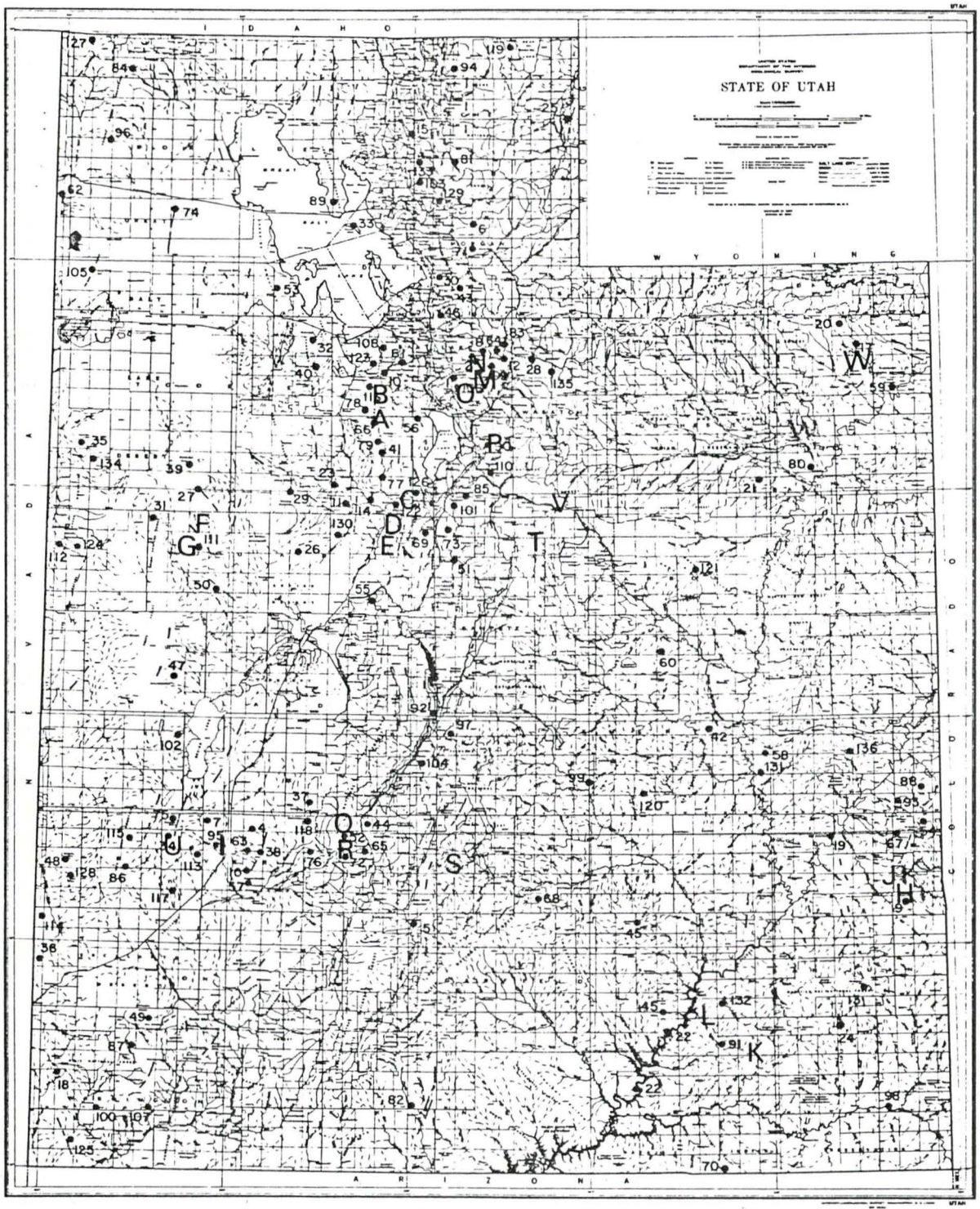


Figure 2. Location of mining localities studied with alphabetic designations that correspond to the sub-sections describing each site.

obtained during each test run. The oven dry sediment was then weighed. Total sediment produced was estimated from the weighed sample by adjusting to grams/liter and then multiplying the measured weight by the total number of liters of runoff measured during a given test.

Tap water was used for machine-applied rain water. Electrical conductivity, salinity, and pH were determined on this water for comparison with runoff waters.

Electrical conductivity and salinity were determined in the field using a conductivity meter made by the Yellow Springs Instrument Company. The Beckman pH meter was used for determination of pH.

II

SITE DESCRIPTIONS

Introduction

This section describes the sites categorically by mining location. Each location is discussed under an alphabetic sub-section. The mines are listed in figure 2 according to the alphabetic symbols assigned each locality.

Within a sub-section describing any mine, a map is included which shows the location, elevation, and aspect of each site. These maps have been reprinted from parts of U.S. Geological Survey 7.5 and 15 minute quadrangles. The site description includes a set of tables showing selected characteristics of each sampling location.

Surface hydrologic characteristics are portrayed on the graphs of infiltration curves also included in each sub-section. These curves represent graphical plots of infiltration rate versus time.

The infiltration rate describes the infiltration capacity of the soil. Infiltration capacity is that rate of infiltration in a soil which will occur when water is supplied to the surface at any rate greater than the infiltration rate at a given instant of time (Young, 1972). The following relationship illustrates this concept.

$$Q = i - f$$

where:

i = rate of rainfall

f = infiltration rate

Q = runoff rate

As long as Q has some positive value, rainfall exceeds infiltration which is the infiltration capacity of the soil.

The graphs of infiltration show the average rainfall rate for a given set of test runs. The infiltration capacity is high initially, falls off rapidly, and eventually declines slowly until it acquires a constant value called the infiltration constant or final infiltration rate. The decrease of infiltration rate with time has been described as an exponential relationship (Philip, 1957 and Horton, 1933). This trend is due to a decreasing hydraulic gradient as water penetrates deeper into the surface (Chow, 1964). It is also caused by the filling of pores with water which decreases capillary forces by dispersion of soil aggregates, swelling of colloids, compaction of the surface and blocking of pores by the impact of raindrops and subsequent detachment of surface particles (Chow, 1964; Satterlund, 1972).

The infiltration curves shown on each graph represent the average curve or mean curve for the points plotted. The mean values were computed for several test runs at each site. The solid line represents

a french curve fit to those points. The dashed line represents the infiltration curve of Horton (1933).

$$f = fe + (fo - fc)e^{-kt}$$

where:

f = infiltration rate at time t

fc = final infiltration rate

fo = initial infiltration rate

k = a constant that depends on soil conditions

e = the base of natural logarithms

This line was obtained for the data by linearizing the exponential function, using a log-transformation, and then applying the least squares method to fit the line and solve for fo and k. A description of the method is outlined in Appendix A. A simple computer program was designed to compute the values rapidly.

Comparison of the infiltration curves in this manner was patterned after the work of Watson (1959) and is a convenient method of showing how close to an exponential relationship the field data actually is. To better illustrate this comparison quantitatively, coefficients of determination (r^2) were computed for each linearized model. This value estimates the amount of reduction of total variation of infiltration associated with the independent variable, time (Neter and Wasserman, 1974). The closer the r^2 value approaches 1, the greater the reduction in variation of infiltration and therefore the greater the certainty of predicting the dependent variable.

Examination of the infiltration curves shows that many fall off rapidly with time. This characteristic curve shape was expected for bare materials being sampled. Final infiltration rates, on the other hand,

appear to be abnormally high for these surface types. As already pointed out, the infiltrometer was expected to overestimate infiltration capacity since a plot frame was not employed. In addition, the drop size of simulated raindrops is only 2.413 mm diameter, much smaller than the 4 to 6 mm raindrops produced by natural convective storms. This means that final drop velocities and therefore the effects of pore blockage by detachment and surface puddling are reduced considerably. The size of this error has not been determined.

A. Five Mile Pass

Five Mile Pass is located just west of Fairfield, Utah, at the southern end of the Oquirrh Mountains. It is the location of several fire clay mines operated by Interstate Brick Company and Utah Fire Clay Company. The mine sampled is said to have been worked by the Utah Fire Clay Company during the 1950s (Hyatt, 1956). It is inactive at the present time.

Ore is derived from clay shales of the Manning Canyon Formation which is partly buried by alluvium and partly exposed in small mountain blocks in this area. The sample spoils consist of limestones and brown, buff to brown, red brown, and purplish brown clay shales from the ore-bearing formation. Other mines in the area have spoils of the same type. Spoils containing overburden produced from alluvium are also present at these other sites but not at the mine sampled.

Table 1 shows selected characteristics of Five Mile Pass spoils. Figures 5 and 6 show infiltration curves for the slope and the flat. A comparison of these curves (figures 5 and 6) shows the effects of compaction on the flat. Compaction increases the bulk density of spoil materials at the surface. This in turn reduces infiltration. Table 1 shows that

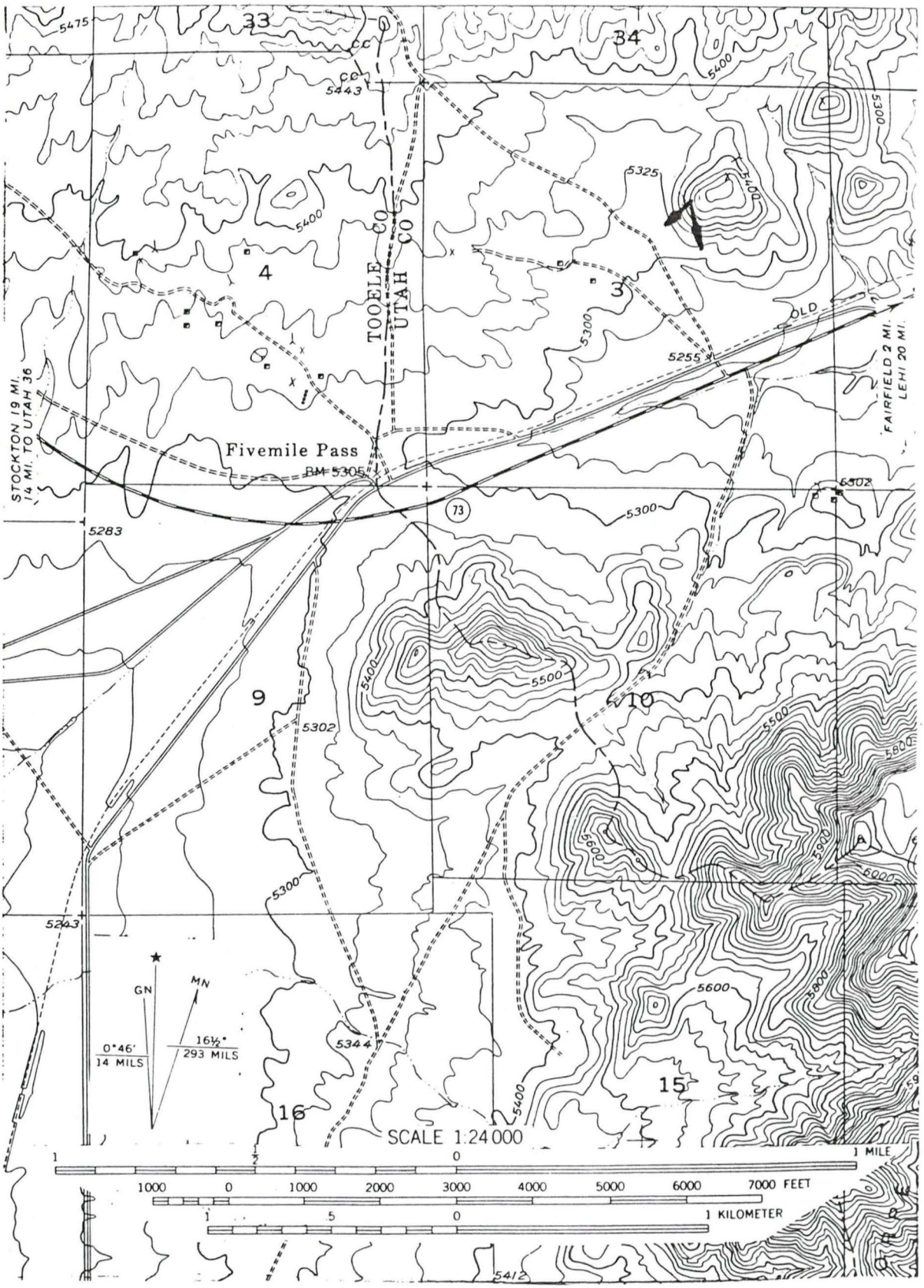


Figure 3. Map of Five Mile Pass area, Utah. Reprint, U.S.G.S. Topographic, 7.5 minute quadrangle.

Figure 4. Five Mile Pass: top, spoils flat with excavation; Bottom, side cast slopes.

Table 1. Selected characteristics of site A, Five Mile Pass.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
Four miles west, Fairfield, Utah	5,400	Osceola	1 acre

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Manning Canyon Shale	Limestones, clay shales	9.78

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
64°F	29.7°F	Artemisia, Chrysothamus

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
S (flats) S.W. (slope)	16 (flats) 70 (slopes)	500 ft (flats) 33 ft (slopes)	7.8	4.9

[a] Hyatt, 1956, Clays of Utah County, and field inspection. Includes only those geologic formations that are represented in the spoils.

[b] U.S. Dept. of Commerce, Weather Bureau, 1960. Data for Fairfield, Utah.

[c] U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 1. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
6.5	.34	1.0	2.8

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
44	clay loam	1.28 slope 1.40 flat

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
38	5,265	8.10

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
1.91	6,872	125.86 (slope) 25.25 (flat)

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 1. Continued

Chemical quality of runoff[f]			
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)		
	water applied	runoff	
19.89 (slope) 3.41 (flat)	1.0	2.9	

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.5	7.9	100	180

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

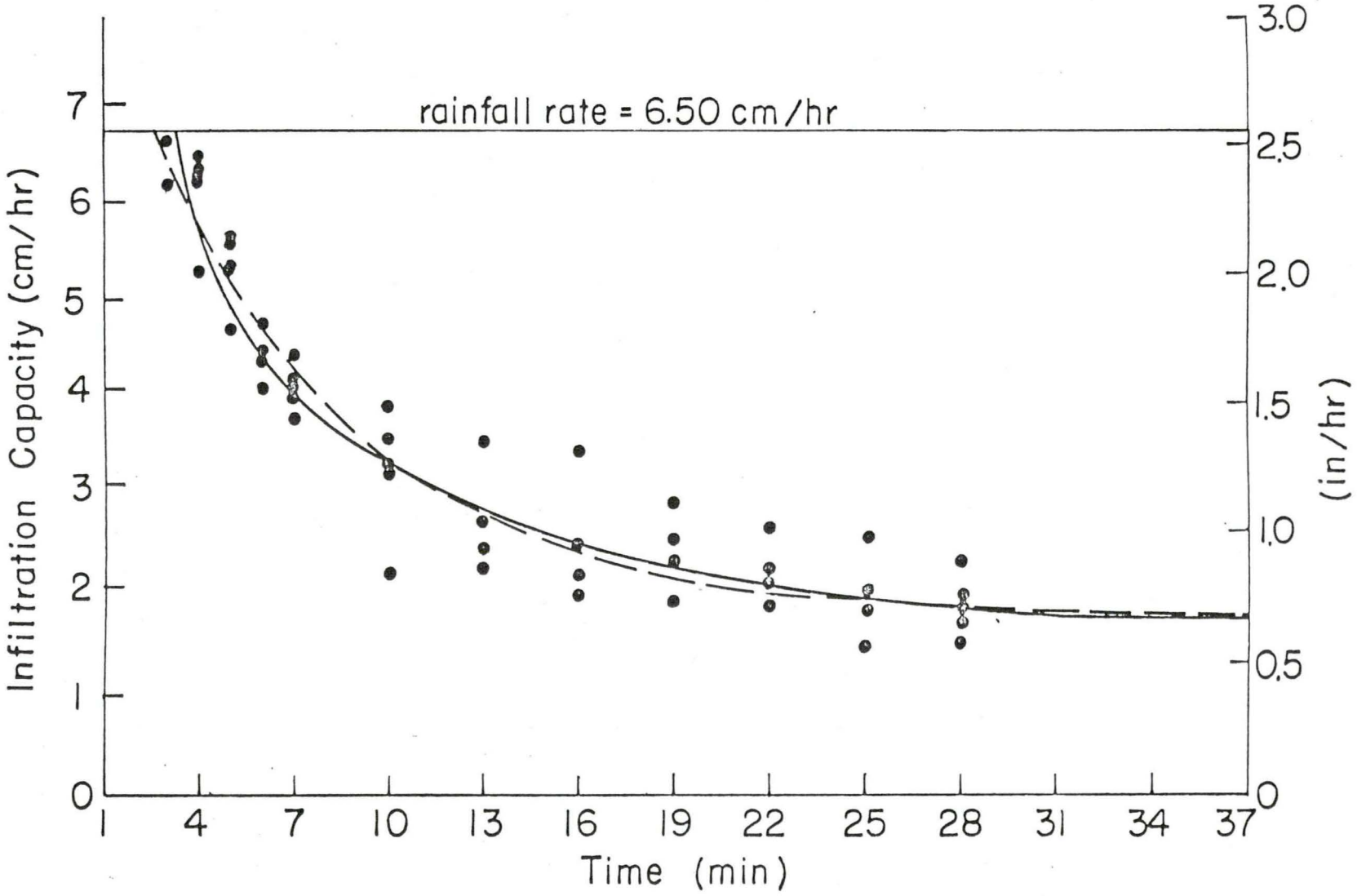


Figure 5. Infiltration curve for Five Mile Pass (slopes).

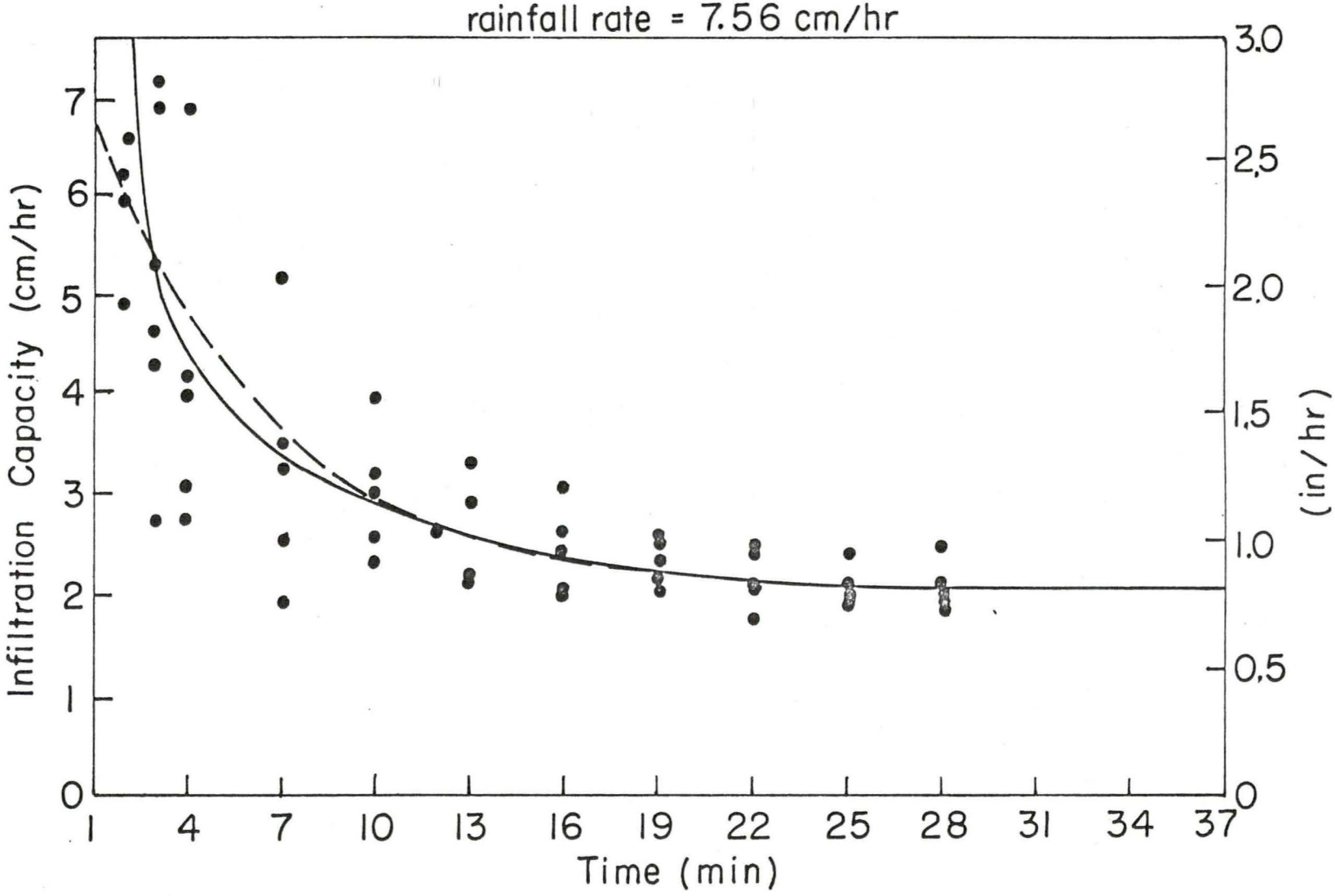


Figure 6. Infiltration curve for Five Mile Pass (flat).

flats have a comparatively low sediment production rate. This, it is believed, is caused by the effects of close grain packing in compacted materials which resist detachment during erosion, and by a lower degree of slope which reduces the energy of overland flow. Compaction on the flat occurs during mining operations when heavy vehicles are used to mine, transport, and dispose of the overburden wastes taken from the open pit (see figure 4). This surface of crushed and compacted spoils materials is quite a contrast to the rocky slopes.

B. Mercur

Mercur is located about 5 miles up Lewiston Canyon in the Oquirrh Mountains (figure 7). This mining area dates back to 1872 when the town of Lewiston, Utah was founded at the present site of the mercur mines by a number of prospectors who had "infested" the area according to Gilluly (1932). In 1879 a German prospector discovered cinnabar (mercury ore) and named the mine that was eventually built the Mercur Mine for the German word for mercury. By 1880 the population of Lewiston had grown to 1500. The Marion mill was constructed at Mercur in 1891 using the cyanide of potassium process to treat newly discovered gold ores. In 1900 the town population had grown to about 2500. At that time the Golden Gate mill processed several tons of ore per day. The large tailings deposit just east of the mercur mine (see figure 8) represents wastes from this mill. During the 1930s, ore was treated in a mill on the northwest side of Mercur. Wastes from this operation were flushed down Lewiston Canyon. Tailings of these deposits today extend to the mouth of the canyon and then spread out on the alluvial fan at the base of the mountains occupying several square miles of land area.

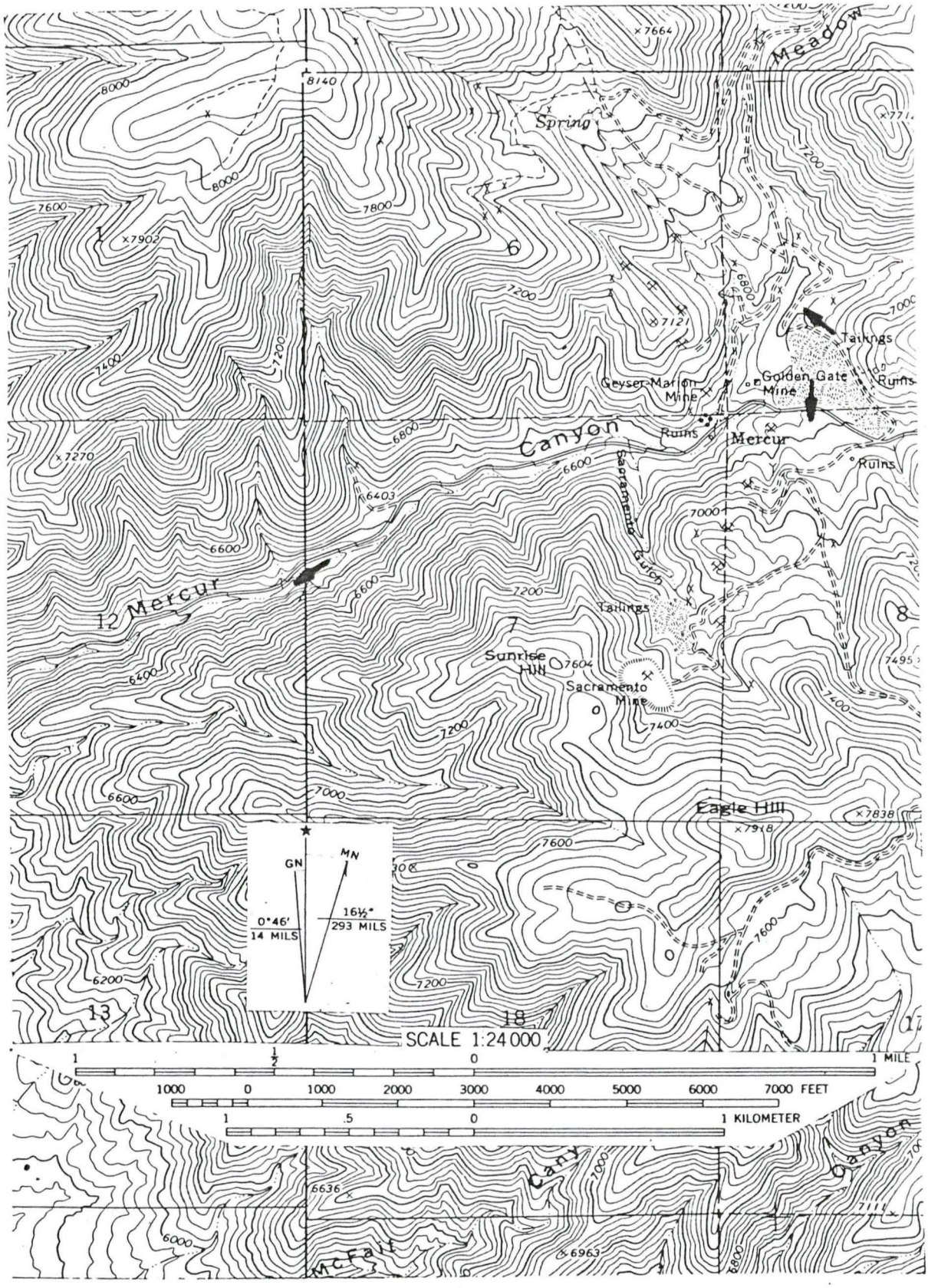


Figure 7. Map of Mercur, Utah. Reprint, U.S.G.S. Topographic, 7.5 minute quadrangle.

Figure 8. Mercur, Utah: Left, the Golden Gate Mine with tailings of the Mercur Consolidated Mines Co., Right, sampling location for slopes on the same tailings.

Two samples of surface hydrology were taken on the Golden Gate deposit and one on the younger deposit in Lewiston Canyon. The Lewiston Canyon tailings are characterized in table 2. Figure 9 shows the infiltration curve for the same. Table 3 shows characteristics of Golden Gate.

Upon examination of table 3 we find that the Golden Gate tailings are similar to those down canyon, in terms of surface hydrology, but only where they were derived from the same type of treatment and disposal. The flat in table 3 has this characteristic.

The slope sample for Golden Gate was taken on tailings that were treated differently. The Golden Gate Mill was situated high on a steep slope above these deposits. When tailings were disposed of, they were removed from the mill using rail cars that would side-cast the wastes immediately below. These tailings are the steep piles illustrated in figure 8.

In later years, tailings were flushed out of the mill into a gully located north of the car-deposited tailings just mentioned.

Surface hydrology was found to be considerably different on the older deposit. Here infiltration rates were beyond the rain producing capacity of the machine. No runoff was collected; therefore, hydrologic data has not been recorded on table 3 for this site.

We might conclude from the foregoing that where similar methods of treatment and disposal of ores mined from the same rocks are employed, the resultant tailings might very well be represented by similar characteristics in terms of surface hydrology. If some other method is used to mill and dispose of the same rocks, a different surface-hydrologic response might result as shown by the example at Golden Gate.

Table2. Selected characteristics of site B2, Mercur-Lewiston Canyon.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
22 miles S.E. of Tooele, Utah	6,320	Camp Floyd	100

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Replacement deposits Great Blue Limestone	--	11.46

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
62.7°F	40.3°F	Quercus, Artemisia, Chrysothamus

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
S.W.	21.1	150 ft.	--	--

[a] Gilluly, 1932. Geology and ore deposits of the Stockton and Fairfield quadrangles, Utah. Includes only those geologic formations thought to be represented in the tailings.

[b] U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, 1974; and Weather Bureau, 1952. Data for Johnsons Pass and Tooele, Utah.

Table 2. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
--	--	--	--

Characteristics of surface materials (cont.)		
Material 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
--	silt loam	1.48

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
--	5,693	8.15

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
2.54	6,444	--

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 3.Selected characteristics of site B1, Mercur-Golden Gate.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
24 miles S.E. of Tooele, Utah	6,800	Camp Floyd	19 acres

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Replacement deposits, Great blue Limestone	--	11.46

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
62.7°F	40.3°F	Quercus, Artemisia, Chrysothamus

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
S (slope)	84.2 (slope)	130 ft (slope)	7.9	11.8
N.S. (flat)	19.2 (flat)	240 ft (flat)		

[a]Gilluly, 1932. Geology and ore deposits of the Stockton and Fairfield quadrangles, Utah. Includes only those geologic formations thought to be represented in the tailings.

[b]U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, 1974; and Weather Bureau, 1952. Data for Johnsons Pass and Tooele, Utah.

[c]U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 3. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
78	.38	2.7	18.6

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
36	sandy loam	1.48

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
28	598 (flat only)	12.67 (flat only)

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
2.24 (flat only)	6,155 (flat only)	--

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 3. Continued

Chemical quality of runoff[f]		
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)	
	water applied	runoff
--	2.0	9.6

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.5	7.9	< 100	850

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

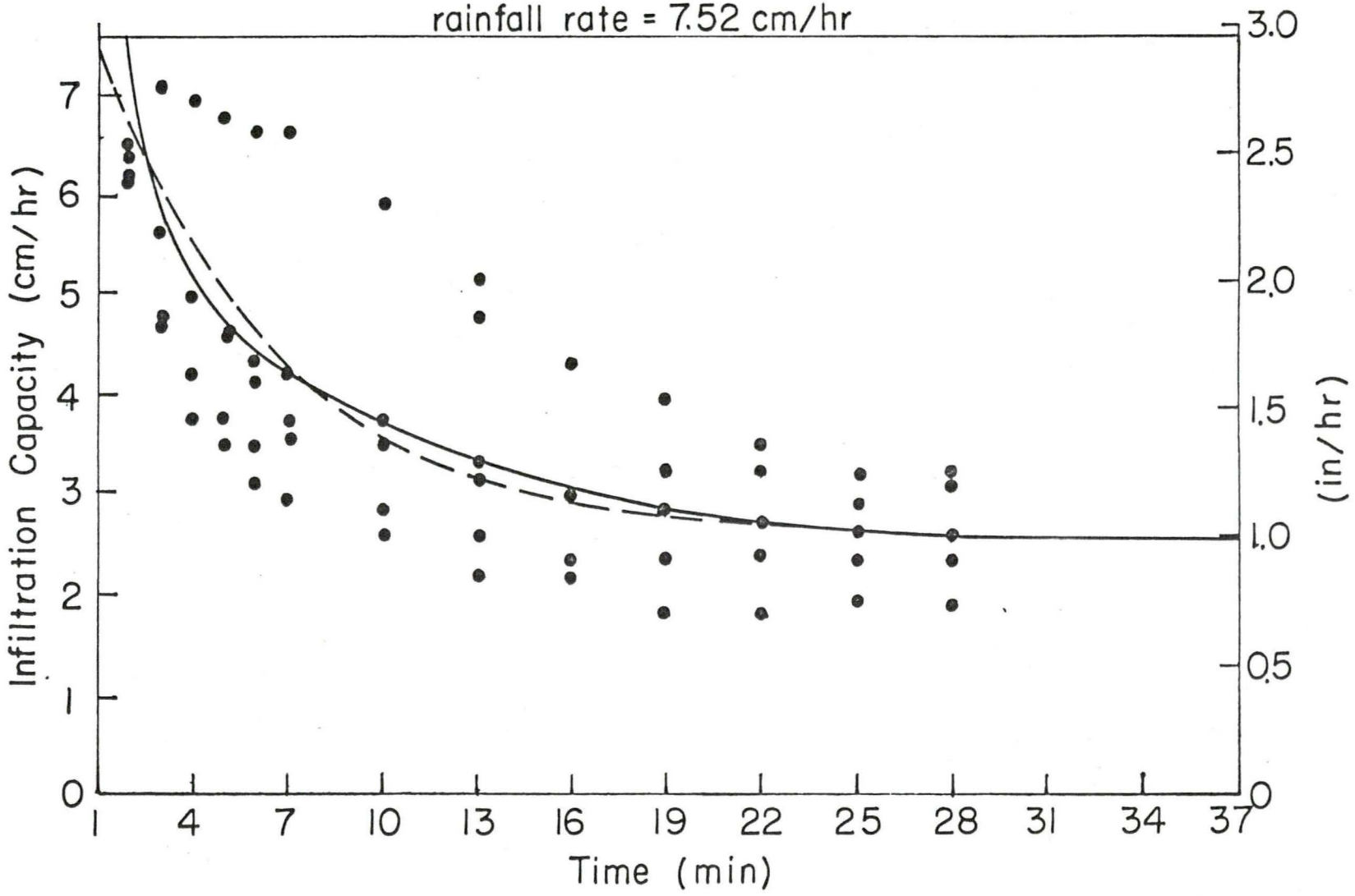


Figure 9. Infiltration curve for the Lewiston Canyon tailings.

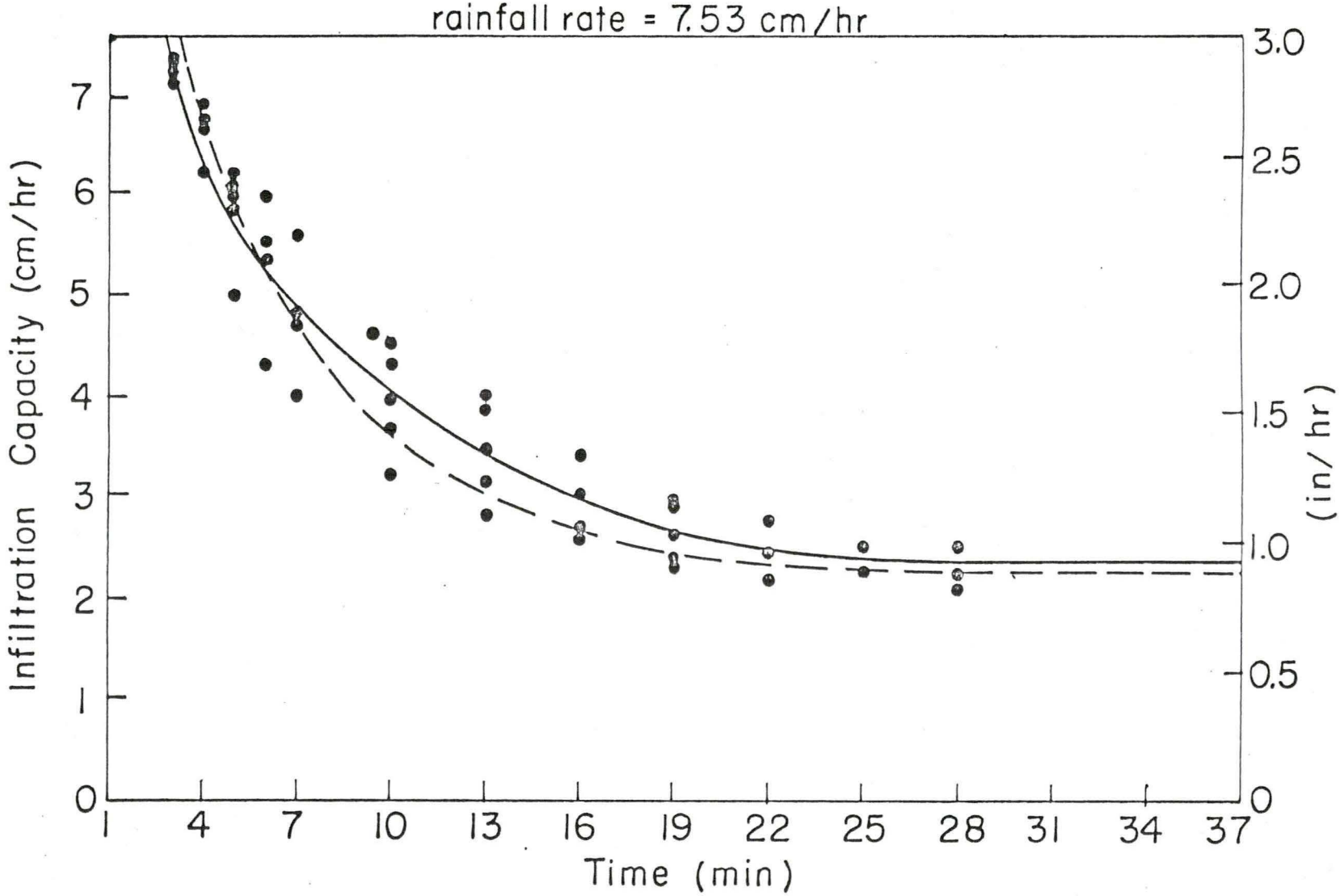


Figure 10. Infiltration curve for Golden Gate tailings.

According to the Handbook of Mineral Dressing (Taggert, 1960), disposal of tailings with the use of cars is a method usually applied to tailings made from dry concentration processes of ore treatment. Gravity flushings are transported by flumes that carry the wet tailings from the mill to the dumping grounds. Wet tailings sampled here are probably the result of the cyanide method of treatment known to have been used at Mercur.

C. Homansville

At Homansville, just east of Eureka, Utah, spoils from a lime mine were sampled. They are derived from the Madison limestone of Mississippian age. The spoils are white deposits of carbonate rich limestone (see figure 12). Weathering has caused caliche concentration of limestone grains over scattered portions of the mine dump. The resultant material, however, is soft and highly porous. The bulk density is only .83 grams/cc (see table 4).

Attempts to measure infiltration rates at this site were fruitless. These materials absorbed falling rain to an intensity of 12 inches/hour and therefore infiltration rates were beyond the capacity of the machine.

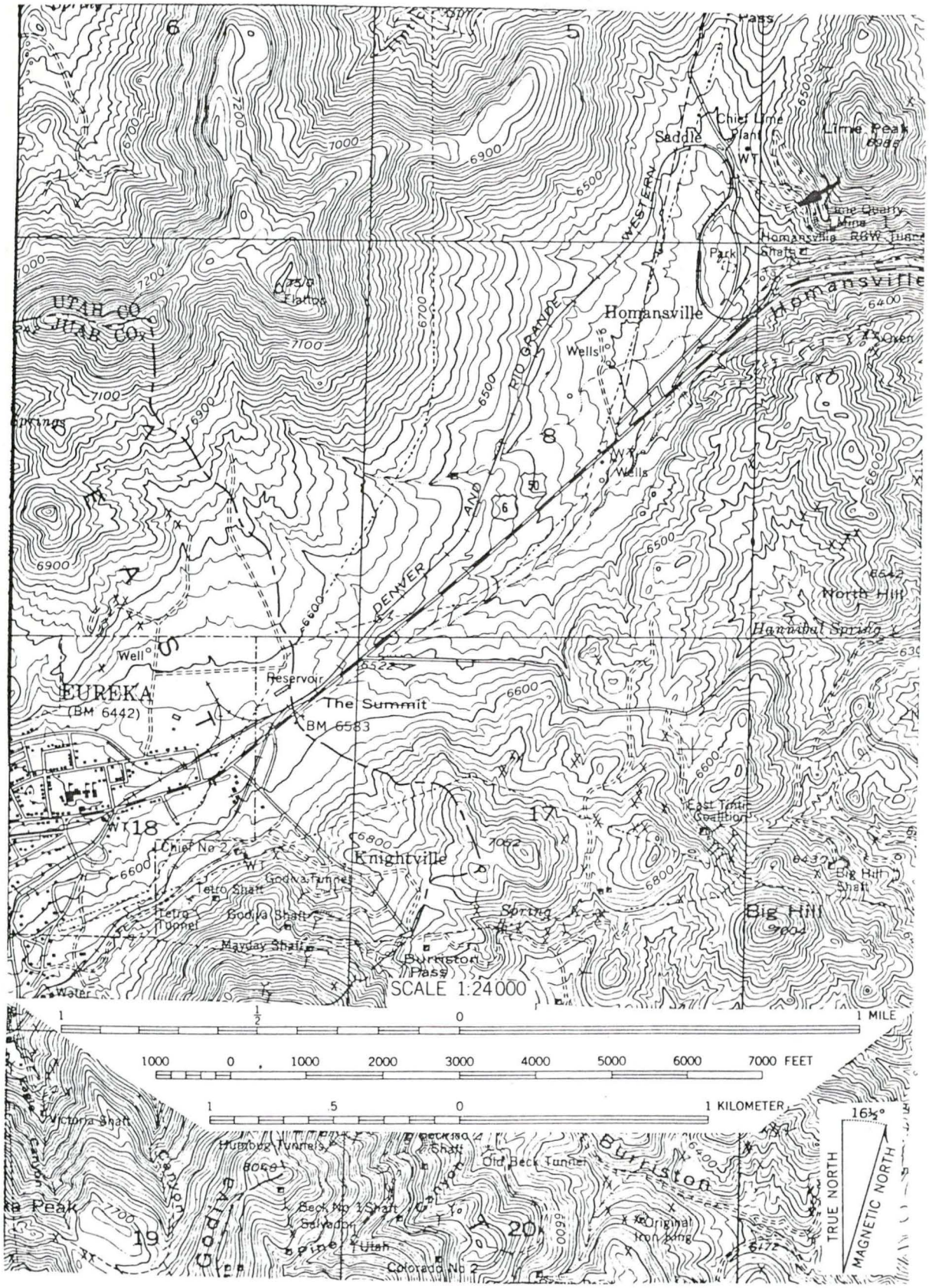


Figure 11. Map of Homansville Lime Quarry, Utah. Reprint, U.S G.S. Topographic, 7.5 minute quadrangle.

Figure 12. Homansville Lime Mine: Top, overall view; Bottom, closeup of caliche-cemented spoils.

Table4. Selected characteristics of site C, Homansville Lime Mine.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
2 miles east of Eureka, Utah	6,500	Main Tintic	10 acres

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Madison Limestone	Limestone and Caliche	14.14

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
64.7°F	35.3°F	Chrysothamus

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
S.W.	70	300 ft.	8.0	1.3

[a]Utah Geological Society (1957), Geology of the East Tintic Mountains and ore deposits of Tintic mining district, and field inspection. Includes only those geologic formations that appear to be represented in the spoils.

[b]U.S. Dept. of Commerce, Weather Bureau, 1960. Data for Eureka, Utah.

[c]U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 4. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
39	.5	.4	.7

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
34	sandy loam	.83

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
70	--	--

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
--	--	--

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

D. Silver City

The Swansea and Four Acres mines at Silver City were among the first to produce ores in the Tintic District. Silver and lead were mined prior to 1896 in the Swansea Rhyolite. After the discovery of a deeper ore body in the silver city monzonite stock in 1896, mining activity was stepped-up (Lindgen and Loughlin, 1919). At present the mines are inactive.

Spoils derived from the rocks mentioned above contain quartz, galena, and a considerable amount of pyrite. The high sulfide content of the spoils is probably the reason for the yellow color in these materials shown by the photography in figure 14.

Two samples of surface hydrology were obtained at this site, one on slopes and another on outwash sediments at the base of the slopes. The latter are labeled "flat" in table 5. Subjects of interest in this table are the low pH and high EC values for both the spoils and the water runoff samples. The acid pH is probably caused by oxidation of the sulfide minerals in the surface. According to Peterson and Nielson (1973), pyrite may react in the presence of oxygen as follows:

$$FeS_2 + H_2O + 3\ 1/2\ O_2 \rightarrow FeSO_4 + H_2SO_4$$

$$2FeSO_4 + H_2SO_4 + 1/2\ O_2 \rightarrow Fe_2(SO_4)_3 + H_2O$$

$$Fe_2(SO_4)_3 + 6H_2O \xrightarrow[\text{hydrolysis}]{} 2Fe(OH)_3 + 3H_2SO_4$$

The high sulfate content of the spoils materials (table 5) and the presence of pyrite (FeS_2) minerals are an indication that the production of sulfuric acid, as illustrated above, operates at this site.

The low pH of the runoff waters (table 5) increases the solubility of toxic ions and metals. As a consequence, the spoils accommodate no vegetation. The high solubility effect may also increase salinity levels

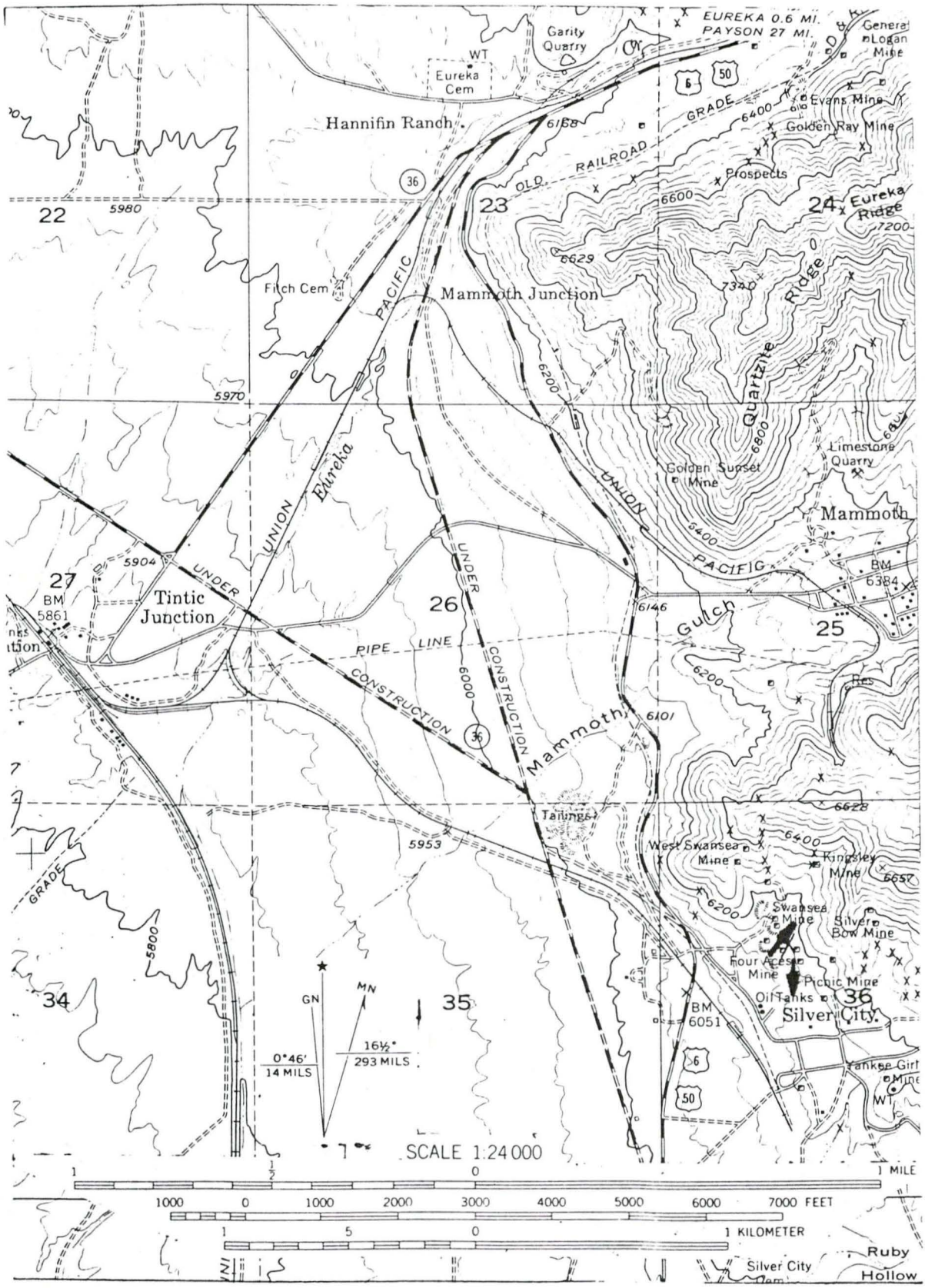


Figure 13. Map of Silver City area Utah. Reprint, U.S.G.S. Topographic, 7.5 minute quadrangle.

Figure 14. Silver City: Top, overall view of spoils or tailings derived from Swansea and Four Acres Mines; bottom, erosion on the same materials.

Table 5. Selected characteristics of site D, Silver City.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
2 1/2 miles south of Eureka, Utah	6,200	Main Tintic	10

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Silver City Monzonite Stock and Swansea Rhyolite	Monzonite, Rhyolite, and sulphides (pyrite, galena)	14.14

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
64.7	35.3	Cercocarpus

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
S	73 (slope) 19 (flat)	20 ft. (slope) 37 ft. (flat)	1.9 (slope) 3.3 (flat)	25.5 (slope) 8.0 (flat)

[a]Utah Geological Society, 1957. Geology of the East Tintic Mountains and ore deposits of the Tintic Mining Districts; also, Lindgren and Loughlin, 1919. Geology and ore deposits of the Tintic Mining District, Utah; and field inspection

[b]U.S. Dept. of Commerce, Weather Bureau (1960). Data for Eureka, Utah.

[c]U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 5. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
7.9 (slope) 3.6 (flat)	.62 (slope) .96 (flat)	<.1	384.5 (slope) 206.6 (flat)

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
56 (slope) 15 (flat)	Silt loam	1.62 (slope) 1.36 (flat)

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
35	4,608 (slope) 7,034 (flat)	4.57 (slope) 7.82 (flat)

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
1.78 (slope) 3.18 (flat)	7,529 (slope) 5,102 (flat)	182.71 (flat only)

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 5. Continued

Chemical quality of runoff[f]		
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)	
	water applied	runoff
35.8 (flat only)	2.1	42.0 (slope) 12.6 (flat)

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.8	2.3 (slope) 5.6 (flat)	<100	2,325 (slope) 775 (flat)

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

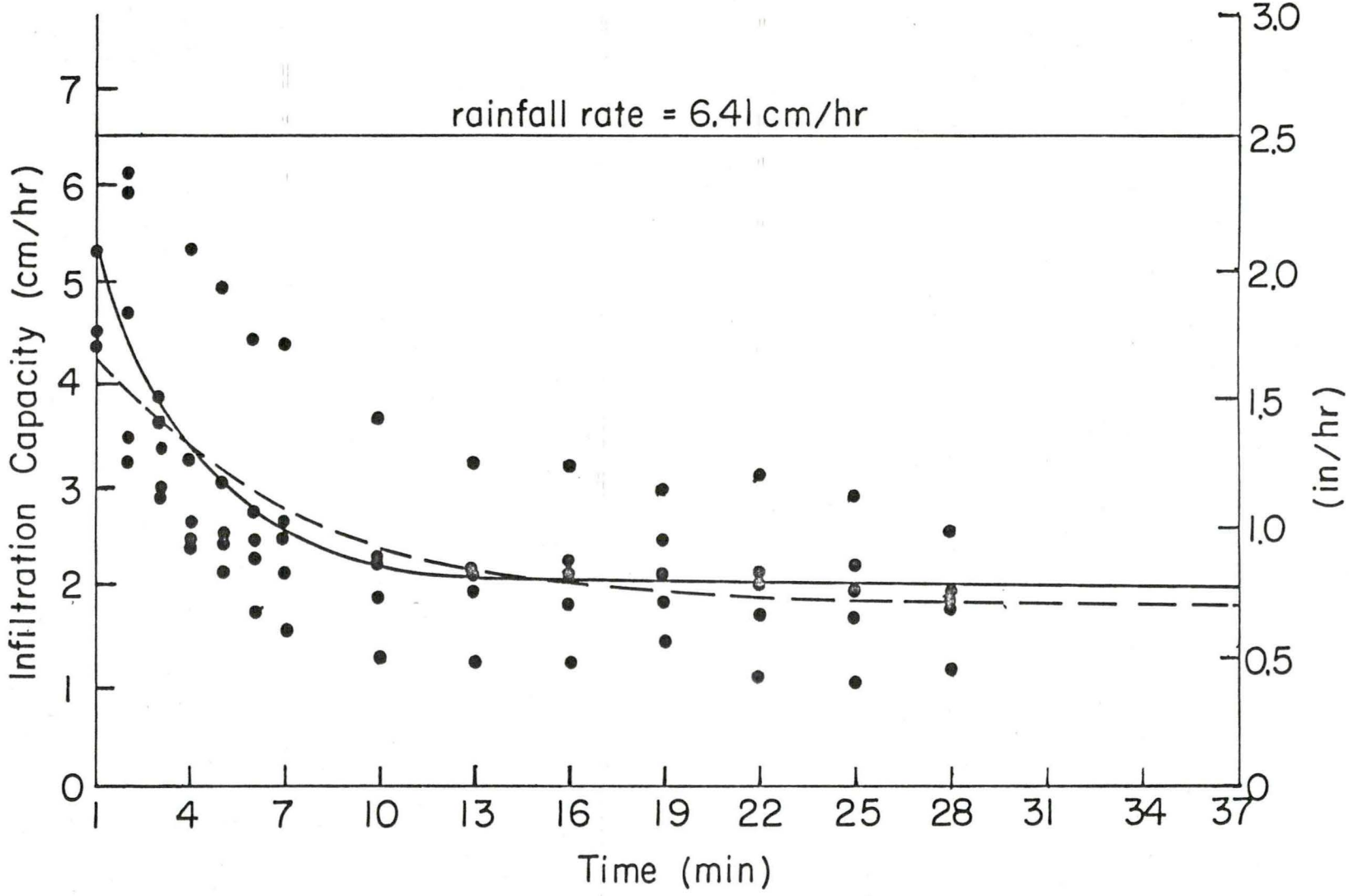


Figure 15. Infiltration curve for the spoils at Four Acres Mine.

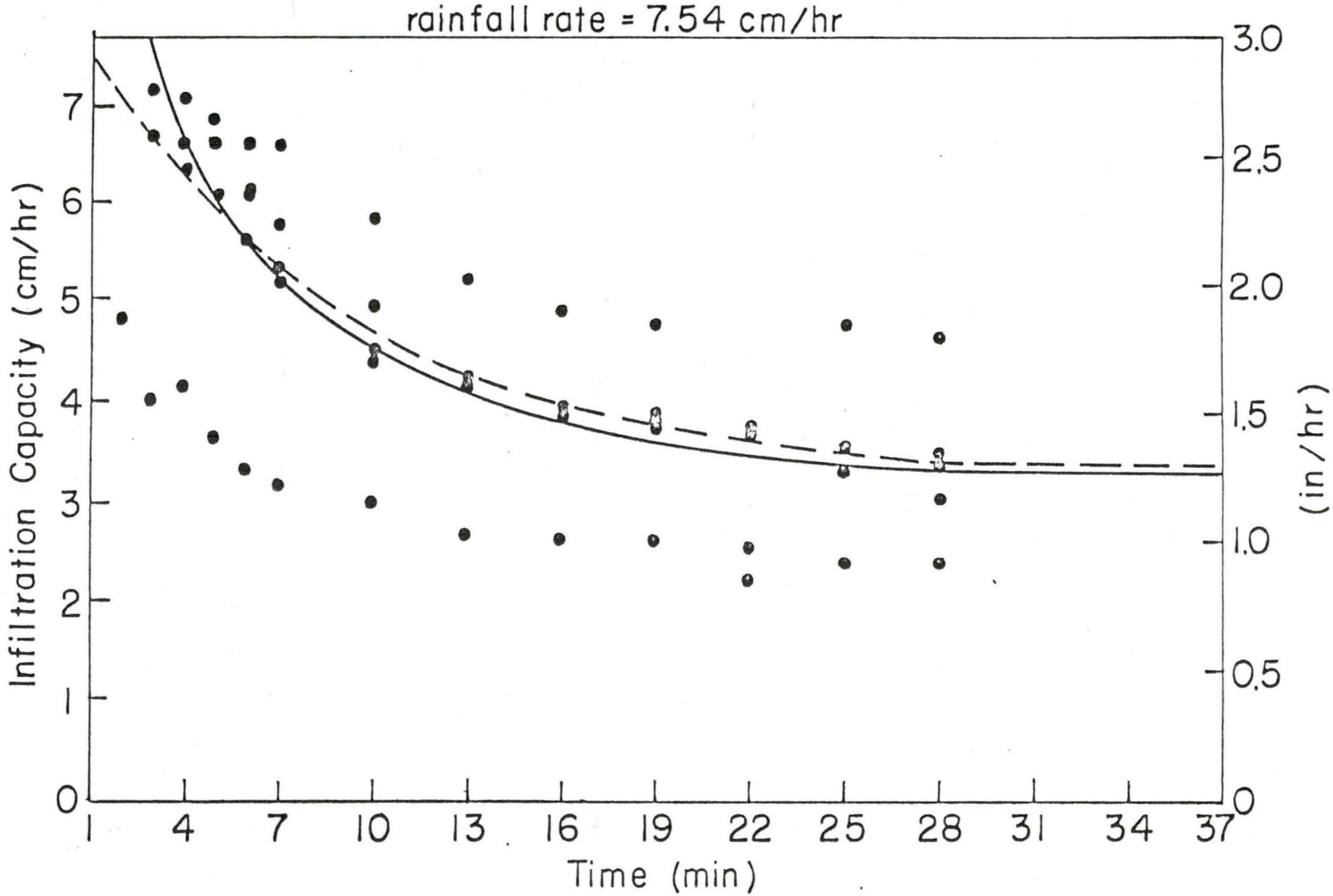


Figure 16. Infiltration curve for the outwash at Four Acres Mine.

measured on the spoils and in runoff waters. As we compare the two samples in table 5 (flat and slope) and in figures 15 and 16, we find that infiltration rates are depressed somewhat on the more acid sample. This same sample was characterized by high bulk density (compaction). Such conditions have also been found on other acid-type mine spoils and tailings.

E. Sunrise Mountain

The Old Susan mine is located just one mile west of the summit of Sunrise Mountain in the East Tintic Range, or about 4 miles south of Silver City. It was in operation during the early 1900s mining lead, silver, and occasionally gold (Lindgren and Loughlin, 1919).

The spoils are derived from monzonite porphyry rocks of the sunrise peak stock (Utah Geological Society, 1957). The ore body is at approximately 317 feet depth below the shaft opening to the mine. Consequently, a large proportion of the spoils consists of barren country rock brought to the surface during tunneling operations. The ore rocks contain kaolinized porphyry sprinkled with pyrite in addition to areas characterized by a quartz-galena-pyrite association, similar to ore bearing rocks at Silver City. The north side of the mine dump contains a pile of spoils that is believed to have been derived from the ore body at depth since it contains sulfide minerals (principally pyrite).

The results of this study make an interesting comparison with Silver City, since acid spoils are present (table 6). The acid spoils are labeled "n. side" and the non-acid as "s. side" in table 6. The acid spoils are characterized by higher salinity levels in both the spoils and the runoff water. The value for bulk density in table 6 is for a composite of the n-side and s-side samples. The north side spoils measured

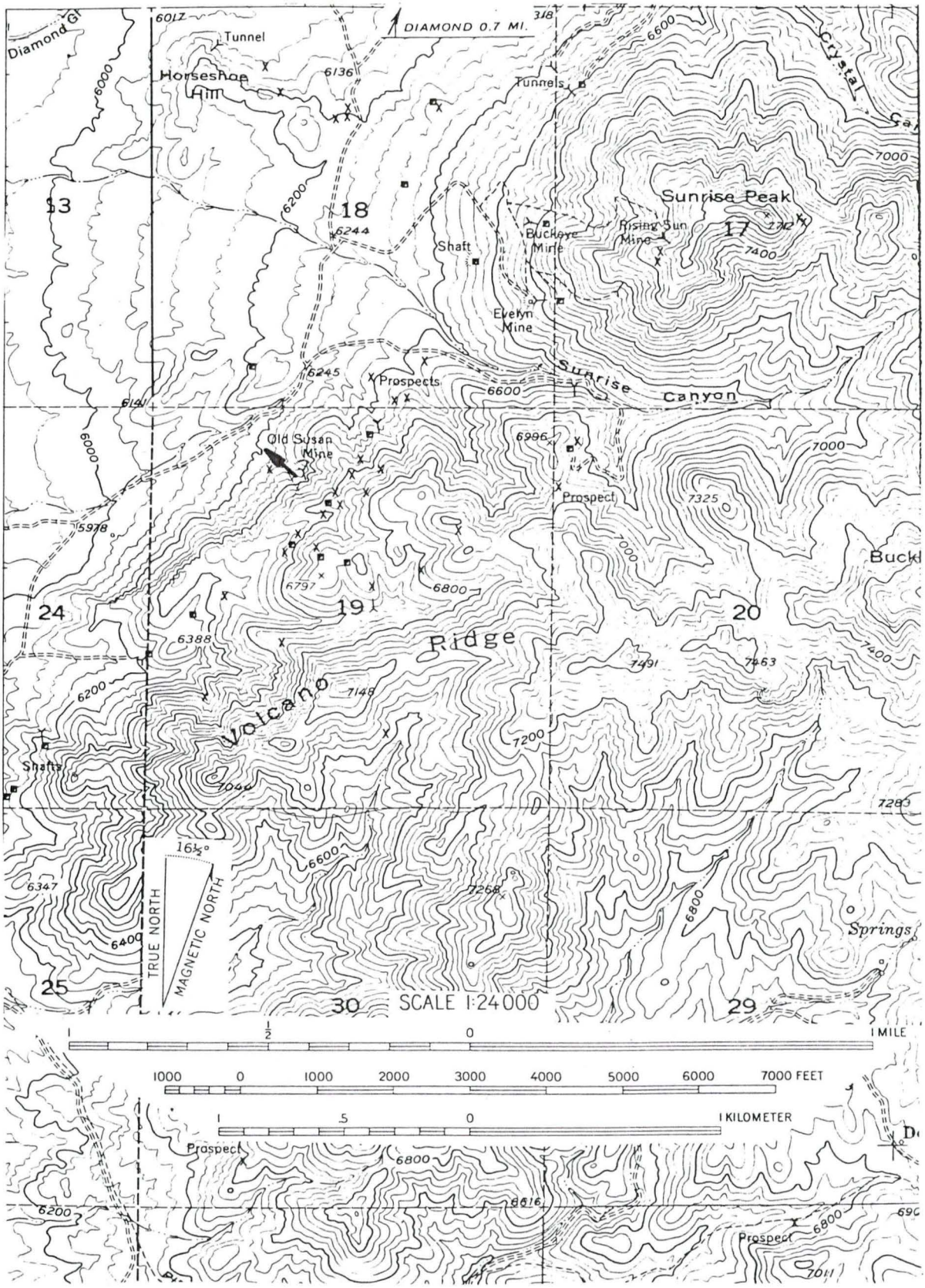


Figure 17. Map of Sunrise Peak area, Utah. Reprint, U.S.G.S. Topographic 7.5 minute quadrangle.

Figure 18. Old Susan Mine in the Tintic Mining District, Utah.

Table 6. Selected characteristics of site E, Sunrise Mountain.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
10 miles south of Eureka, Utah	6,400	Tintic	1

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Sunrise Peak Stock	Monzonite porphyry	14.14

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
64.7	35.3	Pinyon Juniper Sage Rabbit brush

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
W	68	90 ft.	3.6 (N side) 7.4 (S side)	4.9 (N. side) .7 (S. side)

[a] Utah Geological Society, 1957. Geology of the East Tintic Mountains and ore deposits of the Tintic Mining Districts; also, Lindgren and Loughlin (1919). Geology and ore deposits of the Tintic Mining District, Utah; and field inspection.

[b] U.S. Dept. of Commerce, Weather Bureau (1960). Data for Eureka, Utah.

[c] U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 6. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
1.9	.4	.1	1.1 (N. side) .1 (S. side)

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
70	clay loam (N. side) sandy loam (S. side)	1.54

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
29	8,251 (composite)	7.24

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
3.76	3,886	--

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 6. Continued

Chemical quality of runoff[f]			
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)		
	water applied	runoff	
--	2.08	15.8 (N. side) 3.1 (S. side)	

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.8	2.6 (N. side) 7.7 (S. side)	< 100	900 (N. side) 30 (S. side)

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

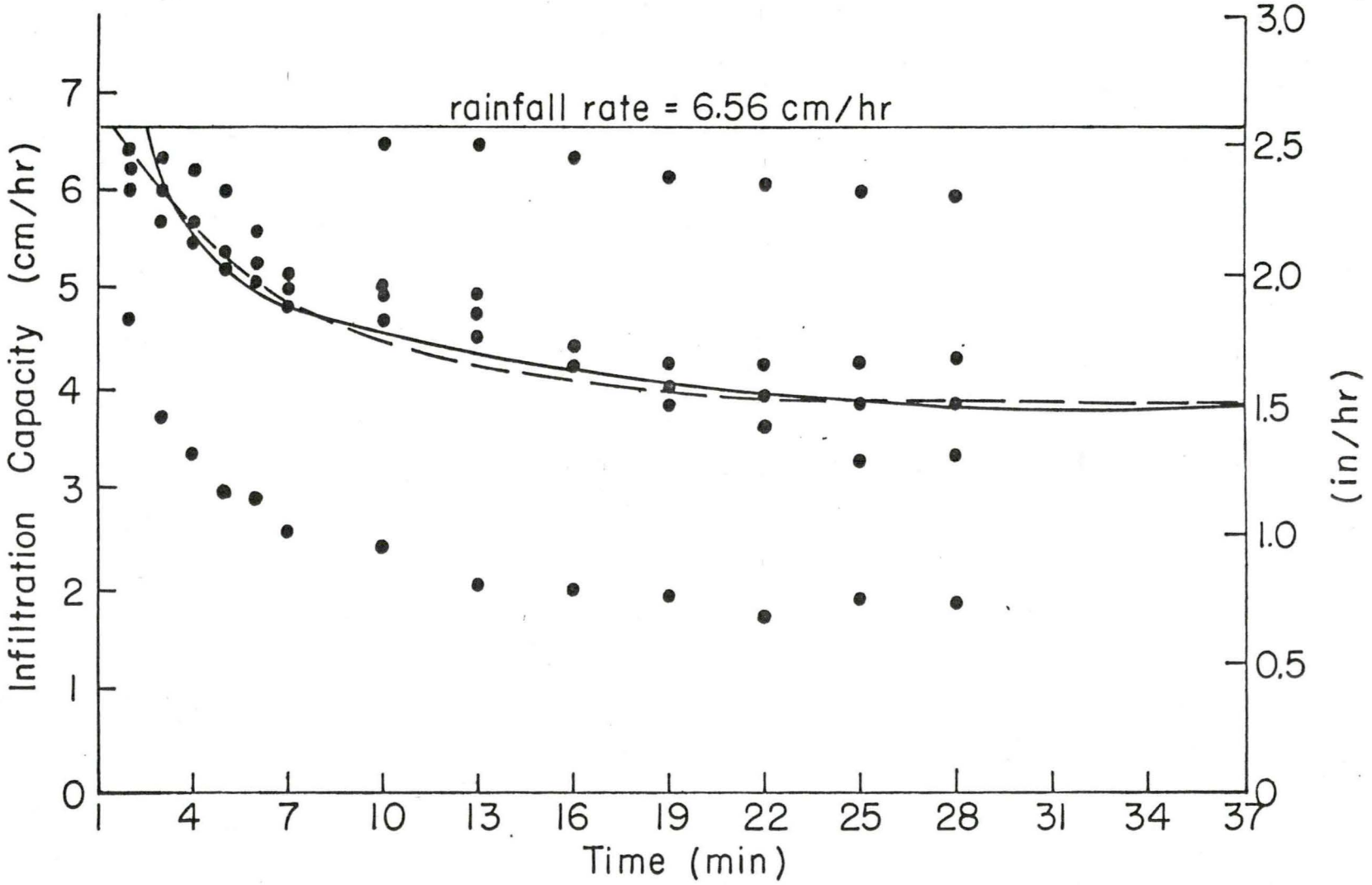


Figure 19. Infiltration curve for the spoils at Old Susan Mine.

a bulk density of 1.73 grams/cc which is considerably higher than the composite.

Figure 19 illustrates infiltration for the mean of the three south side and one north side samples taken at this site. The final infiltration rate is approximately 3.80 cm/hour. The individual sample taken on the north side had a final rate of only 1.83 cm/hour.

These differences are probably due to a combination of the influences of compaction, texture, and acid conditions.

F. Spor Mountain

The flourospar mine sampled for this study is located just below the old Flourine-Queen Mine in the Thomas Range. It is presently mining flourospar in the Spor Mountain area. Flourospar was discovered here in the early 1940s. Ore was produced and sold for metallurgical use in the late 1940s. Most ore after that time was sold to a brokerage firm in New York. Geneva Steel bought ore during the early period (Staatz and Osterwald, 1959).

Spoils from this mining operation contain materials derived from a combination of pit and shaft mining methods. Open-pit mining is used to extract ores from flourospar pipes in the rock. Pipes are followed until the walls of the pit can no longer remain intact at which point shaft mining begins. Spoils materials consist of dolomites, with a complex association of gangue minerals derived from the ore body (Staatz and Osterwald, 1959). Similar conditions exist for many of the flourospar mines in this area. Some of these could be sampled in the future for comparison with the results of this study.

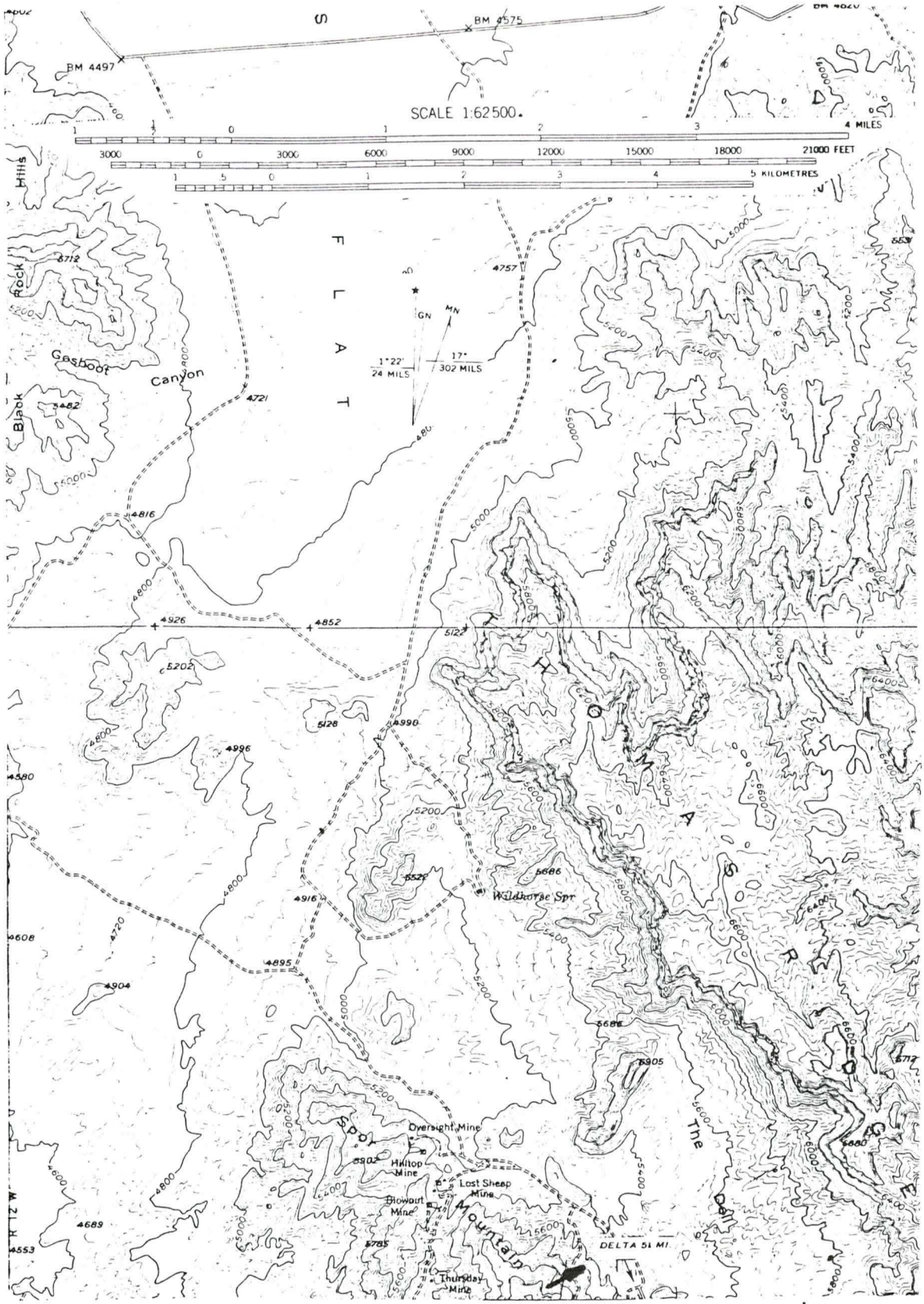


Figure 20. Map of the Spor Mountain area, Utah. Reprint, U.S.G.S. Topographic 15 minute quadrangle.

Figure 21. Spor Mountain flourospar mine: top, overall view bottom, sampling location.

Table 7. Selected characteristics of site F, Spor Mountain.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
51 miles N.W. of Delta, Utah	5,800	Thomas Range	15

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Silurian and Ordovician Dolomites	Breccia pipes of dolomite, clays, quartz, chalcedony	5.18

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
65.7	35.3	Cercocarpus Juniper

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
N.E.	82	100 ft.	7.7	2.5

[a] Staatz and Osterwald, 1959. Geology of the Thomas Range flourospar district, Juab County, Utah; and field inspection.

[b] National Oceanic and Atmospheric Administration, Climatological data (1974); Also U.S. Dept. of Commerce, Weather Bureau (1960). Data for Fish Springs Refuge (1974) and Delta (1960).

[c] U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 7. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
1.7	.3	.4	.1

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
63	Sandy loam	1.68

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
25	8,305	7.72

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
3.25	3,832	80.9

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 7. Continued

Chemical quality of runoff[f]			
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)		
	water applied	runoff	
21.1	3.2	5.9	

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.9	8.0	<100	65

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

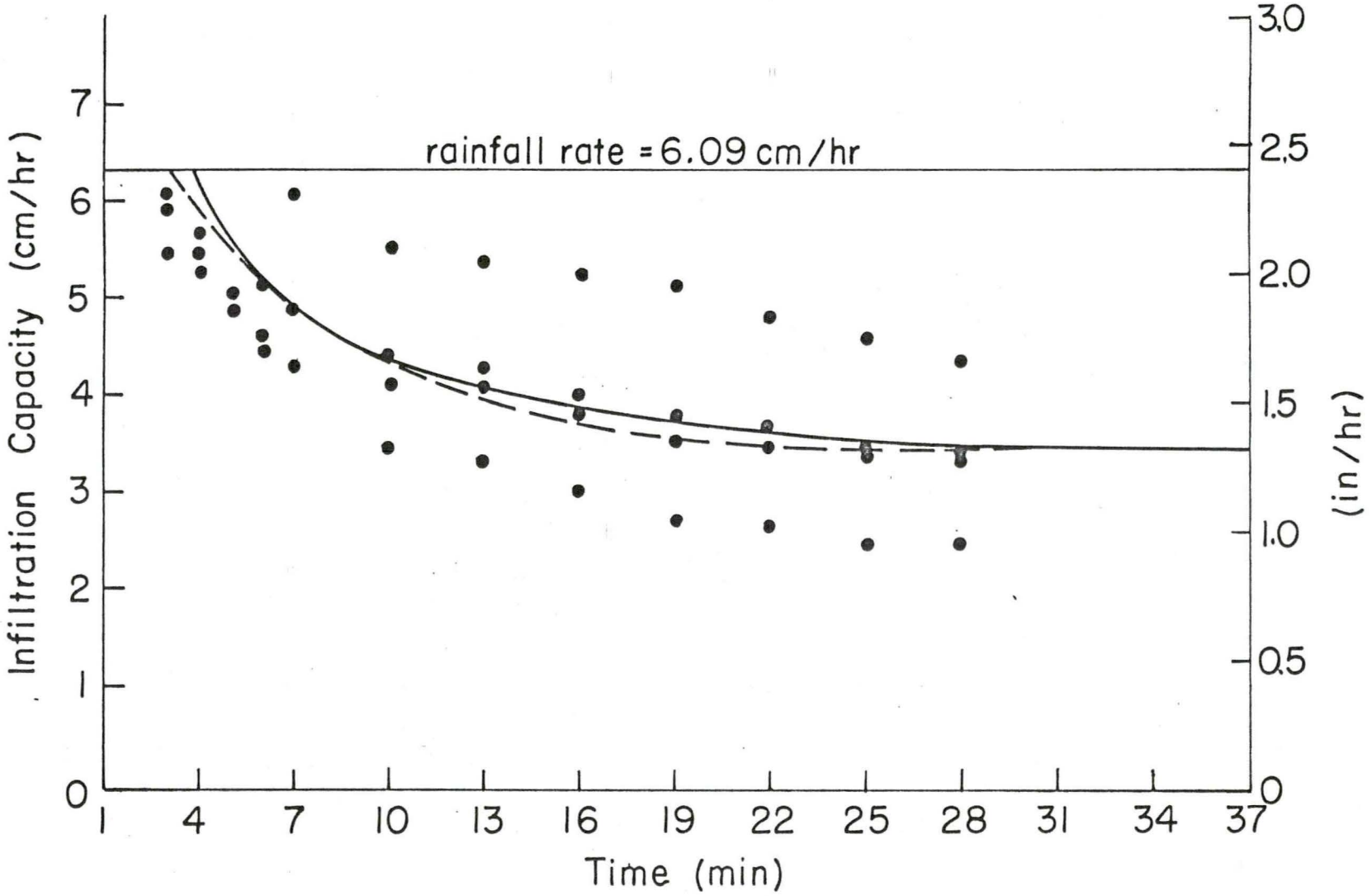


Figure 22. Infiltration curve for the spoils at Fluorine Queen Mine.

G. Brush Beryllium

The Brush Beryllium mine is located on the west side of the Thomas Range in western Utah. Exploratory work in the early 1960s lead to the discovery of a sizeable ore body in the vitric tuffs at the base of Spor Mountain. The Brush-Wellman company began production in the late 1960s.

The mining spoils sampled for this study (figure 24) were deposited in 1969 and 1970 (Kenneth Poulson, mining division manager, personal communication). They are made up of volcanic ash and fragments of pumice derived from altered tuffs. The tuff beds are fairly porous and permeable making them a favorable site for alteration (Staatz, 1963). As a result, most of the glass has been replaced and the resulting altered beds (and spoils) contain a considerable amount of fine grained material including montmorillonite clay.

The mine dump sampled shows evidence of surface erosion by the number of rills and small gullies in the surface. This is surprising since the average annual rainfall for this valley as recorded at Fish Springs refuge is only about 5 inches (table 8).

A sample was taken on the upper surface of the spoils, since it had been worked by a bulldozer, to compare the compacted surface to the non-compacted slope. Figures 25 and 26 show infiltration curves for the two samples. The infiltration curve for the flat (compacted surface) is only slightly lower than that for the slope.

H. Keystone-Wallace

The Keystone-Wallace copper mine is located at the northern end of Lisbon Valley adjacent to the well-known Big Indian Mine near La Sal, Utah. The mine is an active open-pit operation. Spoils consist of overburden

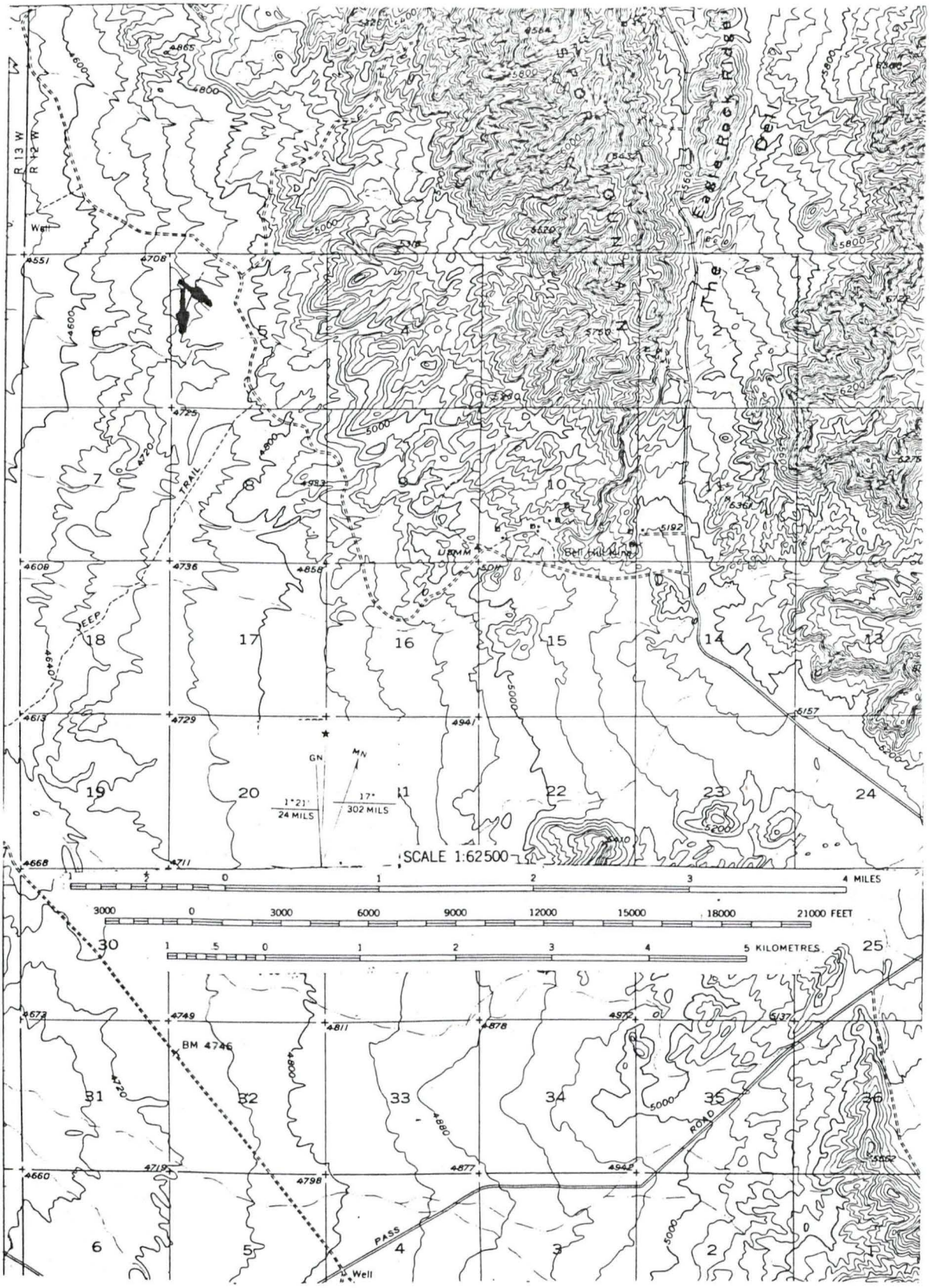


Figure 23. Map of the Beryllium mining area near Brush Beryllium Mine. Reprint U.S.G.S. topographic, 15 minute quadrangle.

Figure 24. Brush Beryllium: top, open pit mine with sampling location in foreground; bottom, sampling area for spoils slopes.

Table 8. Selected characteristics of site G, Brush Beryllium.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
45 miles N.W. of Delta, Utah	4,800	Thomas Range	200

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Tertiary volcanics	Vitric tuff	5.18

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
65.7	35.3	Artemisia

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
S(slope) S.E. (flat)	55(slope) 13 (flat)	50 ft (slope) 200 ft (flat)	7.8	7.0

[a] Staatz (1963). Geology of the Beryllium deposits of the Thomas Range, Juab County, Utah; and field inspection.

[b] National Oceanic and Atmospheric Administration, climatological data (1974); Also U.S. Dept. of Commerce, Weather Bureau (1960). Data for Fish Springs Refuge (1974) and Delta (1960).

[c] U.S.U. Soil, Plant, and Water Analysis Laboratory.

Table 8. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
1.3	.2	4.4	1.2

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
18	Sandy clay	1.00 (slope) 1.20 (flat)

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
92	7,657 (slope) 5,915 (flat)	9.55 (slope) 9.40 (flat)

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
2.29 (slope) 2.69 (flat)	4,880 (slope) 6,222 (flat)	137.0 (slope) 46.2 (flat)

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 8. Continued

Chemical quality of runoff[f]			
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)		
	water applied	runoff	
30.6 (slope) 7.4 (flat)	3.2	5.6	

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.9	8.2	<50	80

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

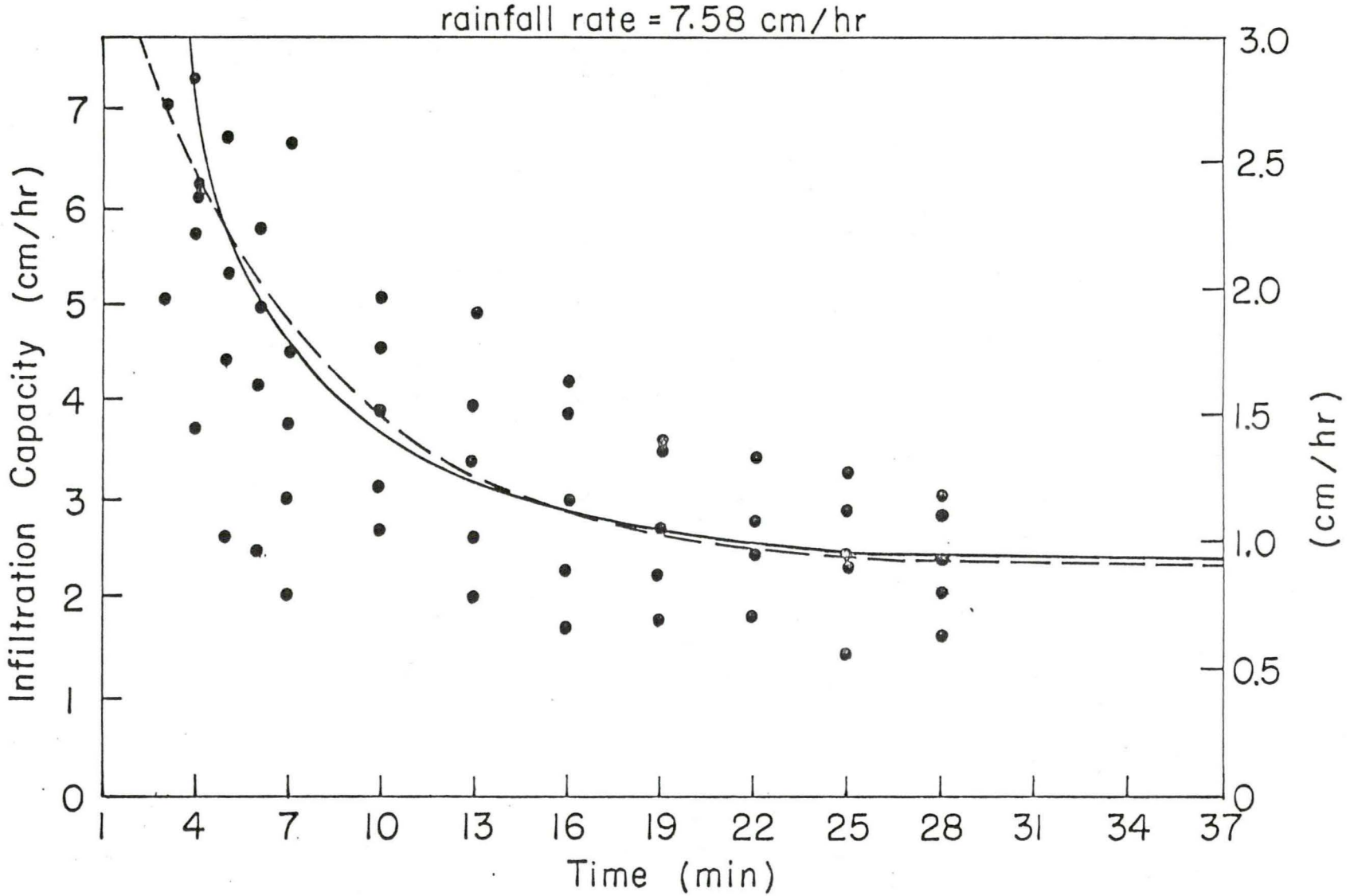


Figure 25 Infiltration curve for the spoils at Brush Beryllium (flats)

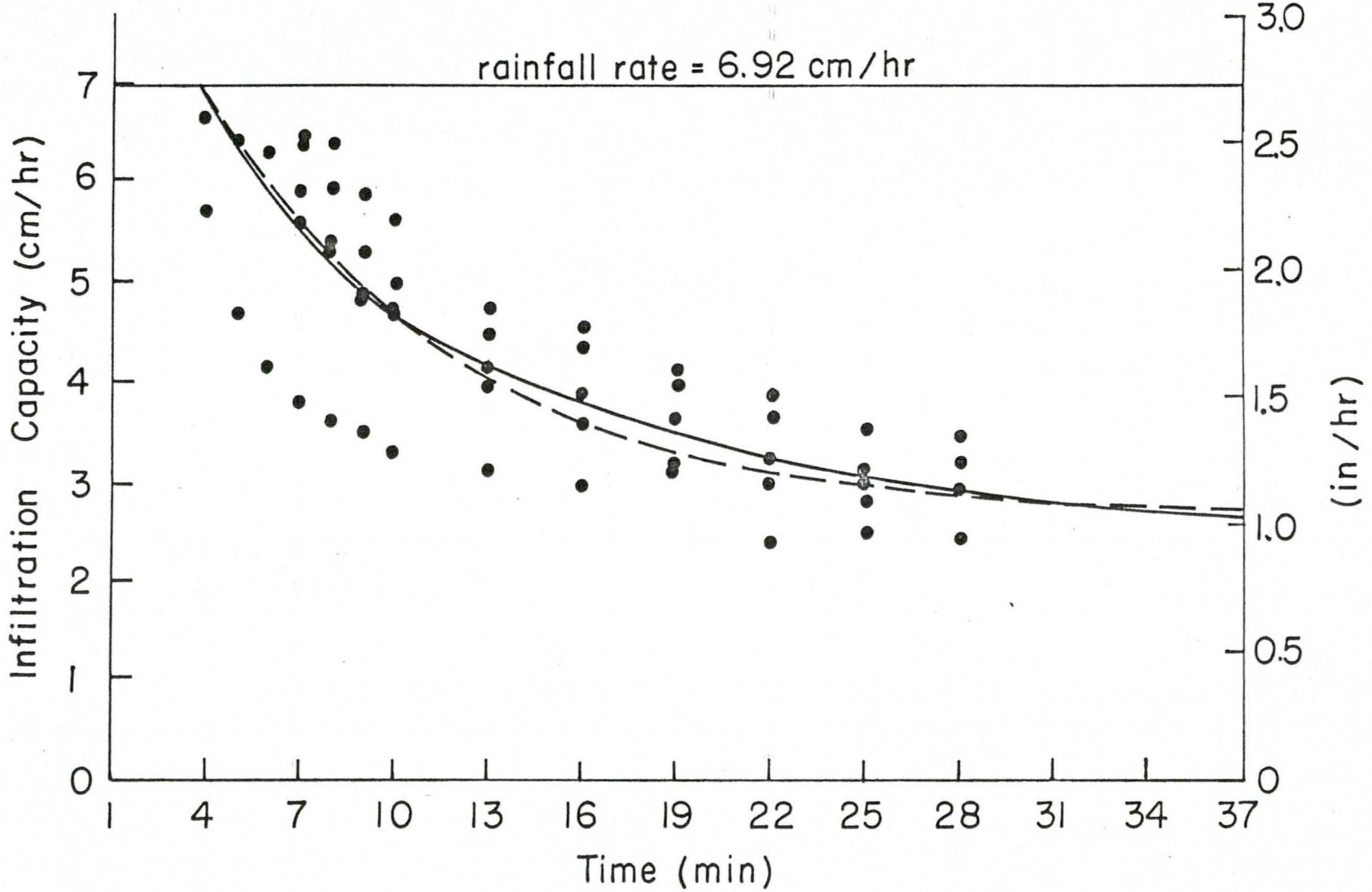


Figure 26. Infiltration curve for the spoils at Brush Beryllium (slopes).

mined from alluvium and partly mixed with sandstones of the Dakota and Burro Canyon Formations of early Cretaceous age. The latter consists of light gray to tan sandstones. In adjacent areas these rocks are apparently overlain by light green mudstones, siltstones, and shales (Carter and Gualtieri, 1965). The alluvium appears to have been derived from a combination of these rock types.

Several mine dumps on these properties have been regraded and at least one of these was seeded. Two samples were obtained for a pair of regraded piles. One is covered with vegetation and the other is bare. The photographs in figures 28 and 30 show these two sites. Figure 28 shows spoils that were seeded with crested wheat several years ago. Natural species have moved onto the spoils quite successfully, but the Crested Wheat has not survived. The spoils in figure 30 were regraded in 1974 and at present support no species of vegetation.

Tables 9 and 10 show selected characteristics of the two sites and make for an interesting comparison. The vegetation-covered spoils are obviously more fertile. They have a silt loam texture (with only 4% of the grains larger than 2 mm) and higher phosphorous and organic carbon contents. The bare spoils, on the other hand, have a significantly higher infiltration capacity (figures 29 and 31) than the vegetated type.

These obvious differences reflect primarily the different geologic origins of spoils materials. The revegetated spoils, at least at the surface, consist of alluvium that was removed as overburden in the mining operation and that once supported plant life. The bare spoils consist of resistant sandstones and quartzites from the Dakota Formation that underlies the alluvium.

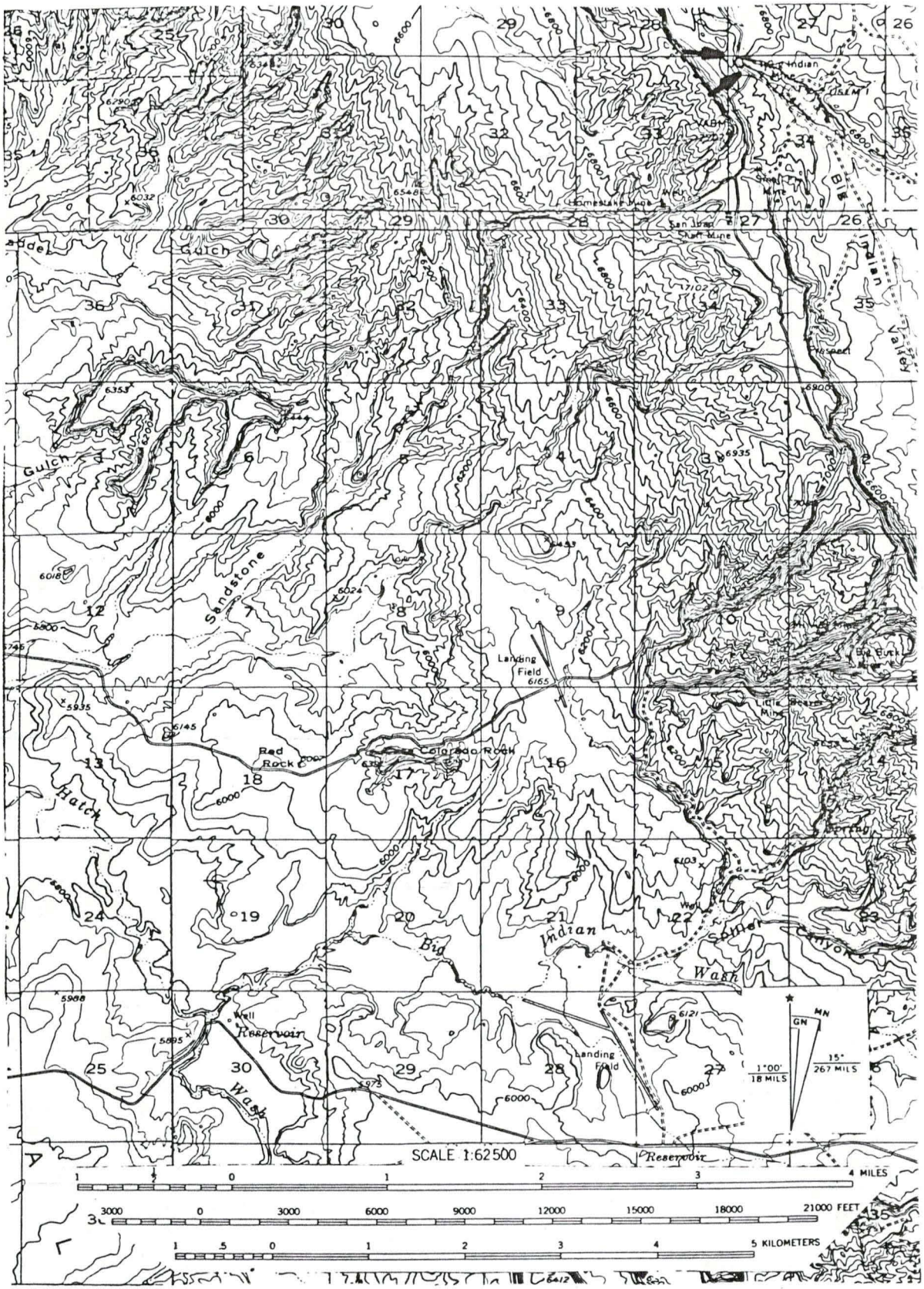


Figure 27. Map of the Big Indian area, Utah. Reprint, U.S.G.S. topographic, 15 minute quadrangle.

Figure 28. Keystone-Wallace copper mine: overall view of mining operations in the Dakota sandstone.

Figure 28. (Continued) Top, regraded spoils covered with valley fill; bottom, same spoils showing natural revegetation.

Table 9. Selected characteristics of site H1, Keystone-Wallace Revegetated Spoils.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
10 miles south of La Sal, Utah	6,800	Big Indian	1

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Dakota Sandstone, Alluvium	Sandstone	12.41

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
59.1°F	32.9°F	Pinyon Juniper

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
E	27	150 ft.	7.6	1.1

[a] Carter and Gualtier, 1965. Geology of the uranium-vanadium deposits of the LaSal quadrangle, San Juan County, Utah, and Montrose County, Colorado; and field inspection.

[b] U.S. Dept. of Commerce, Weather Bureau, 1960. Data for La Sal, Utah.

[c] U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 9. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
13.0	.4	< .1	< .1

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
4	silt loam	1.33

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
39	6,300	6.88

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
3.18	5,838	9.21

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 9. Continued

Chemical quality of runoff[f]			
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)		
	water applied	runoff	
1.57	7.4	7.5	

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.7	7.5	400	475

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

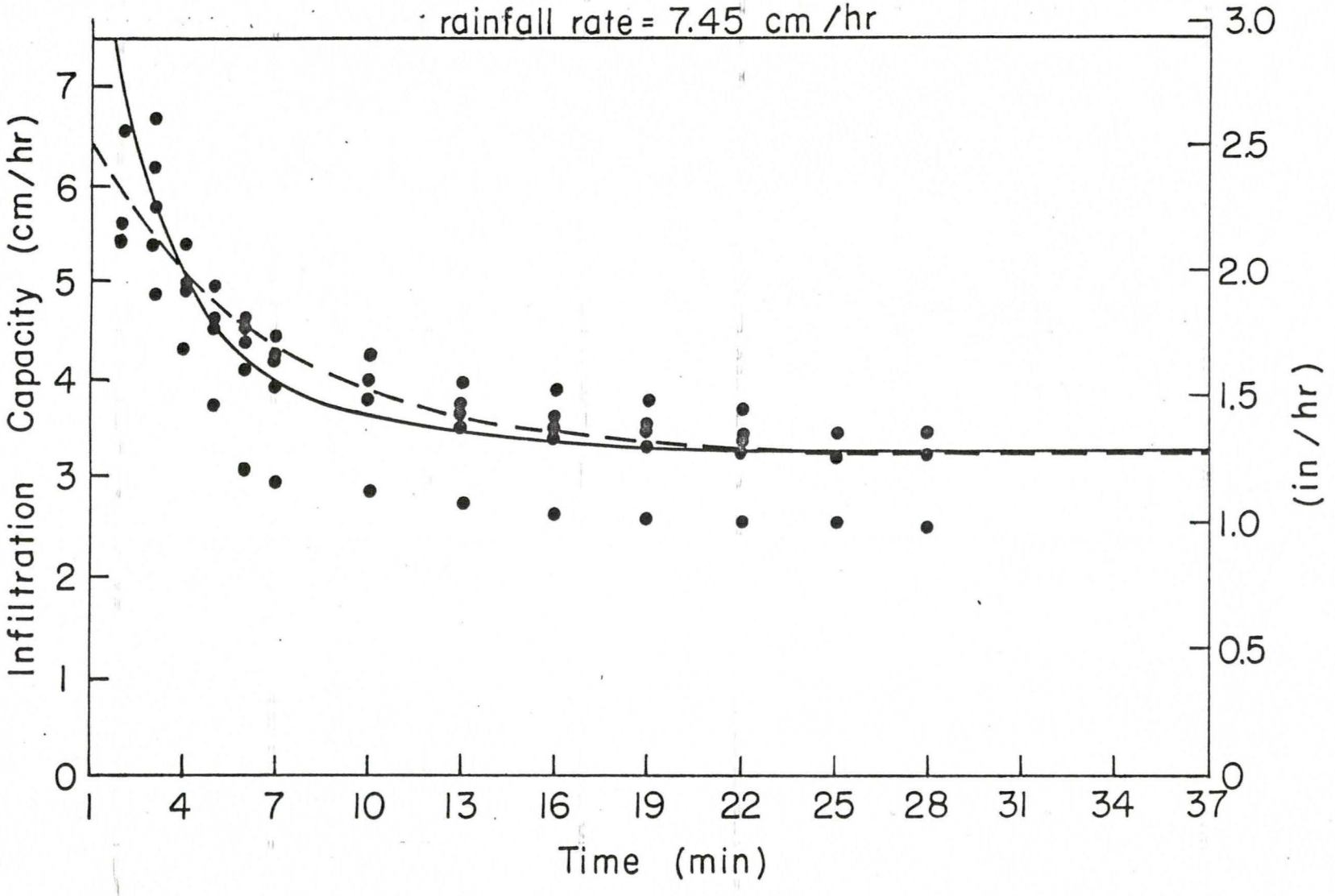


Figure 29. Infiltration curve for the revegetated spoils at Keystone Wallace.

Figure 30. Keystone-Wallace copper mine: top, regraded spoils consisting of Dakota sandstone; bottom, close up of the same spoils.

Table 10. Selected characteristics of site H2, Keystone-Wallace Spoils.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
10 miles south of La Sal, Utah	6,800	Big Indian	2.5

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Dakota sandstone	Sandstone Quartzite	12.41

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
59.1°F	32.9°F	Pinyon Juniper

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
E	23	250 ft.	7.5	.4

[a] Carter and Gualtieri, 1965. Geology of the uranium-vanadium deposits of the La Sal quadrangle, San Juan County, Utah, and Montrose County, Colorado; and field inspection.

[b] U.S. Dept. of Commerce, Weather Bureau, 1960. Data for La Sal, Utah.

[c] U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 10. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
3.0	.1	.1	.2

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
49	sandy loam	1.54

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
36	10,561	7.75

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
5.97	1,576	1.13

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table10. Continued

Chemical quality of runoff[f]		
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)	
	water applied	runoff
.71	7.4	7.4

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.7	7.7	400	450

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

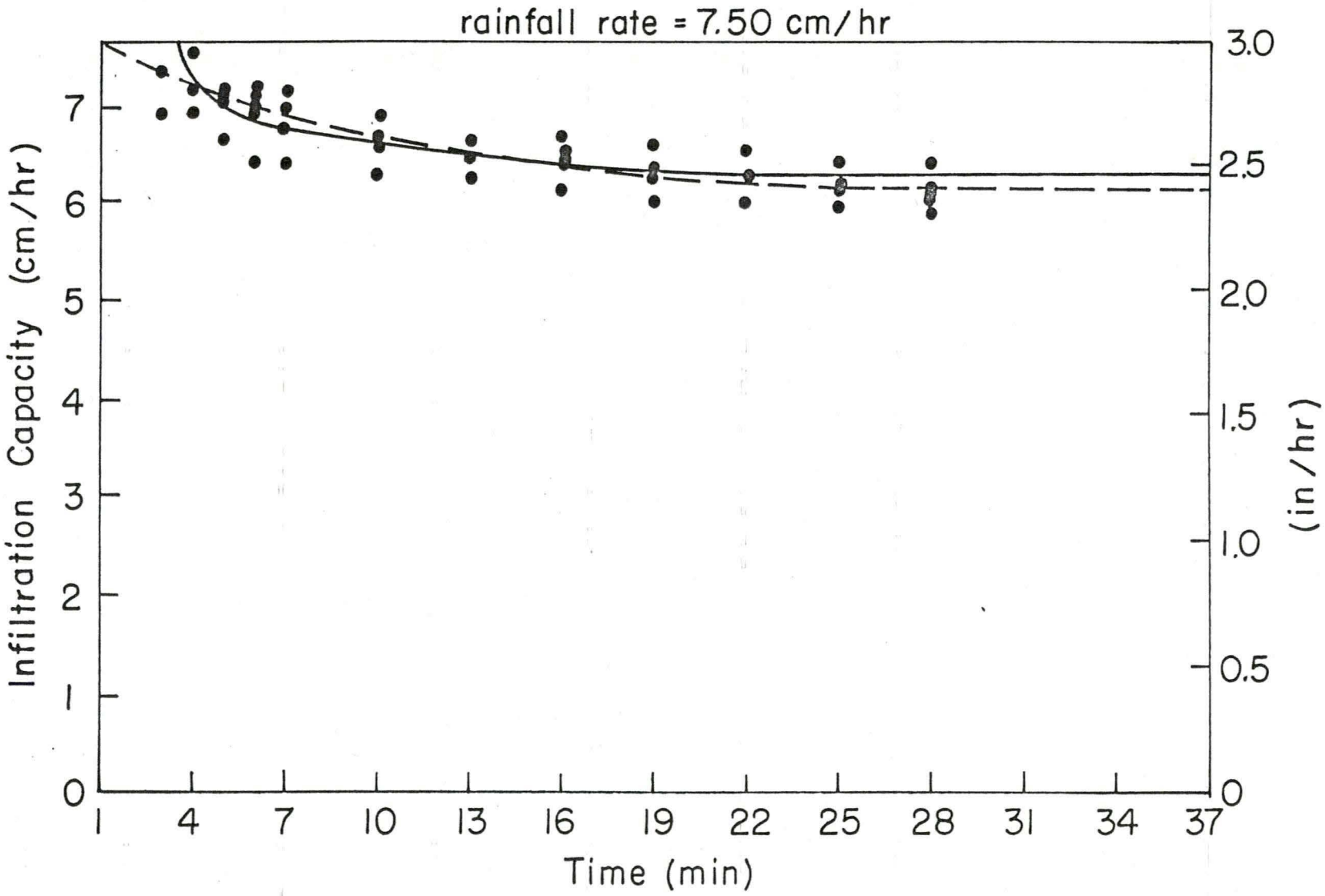


Figure 31. Infiltration curve for the regraded spoils at the Keystone Wallace Mine.

I. Milford

Two copper mines, the Bowana and Old Hickory, were sampled in the Rocky Mining district located 5 miles northwest of Milford, Utah. The two mines are adjacent to each other but surprisingly different in many ways.

The Old Hickory mine produced copper and magnetite ores for a period during the early 1900s. Magnetite was used for flux in the smelters. The mine is situated on a bench where two verticle shafts cut surface float, quartzites, quartz monzonites, and skarn to a depth of 300 feet. Within the shafts are 1,200 feet of drifts and crosscuts (Butler, 1913). In 1941 the north shaft was retimbered and worked for tungsten. The spoils sampled at this mine probably represent the wastes of these later workings since they are located adjacent to the large head frame of the north shaft (figure 33). Spoils consist of low-grade ore and barren rocks brought to the shaft portal by wheeled skips. Waste products were simply side cast down the slopes surrounding the portal.

The Bowana mine, located a few hundred feet north of Old Hickory (figures 32 and 35), is an open-pit type. It was discovered in 1960 and came into operation in 1962 (J. A. Whelan, personal communication). It was mined for copper ores by the Bogdanich Mining Company. About 400,000 tons of ore were removed and an unknown amount of overburden was disposed of adjacent to the pit. The spoils associated with this mine are principally overburden materials produced from skarn and quartz-monzonite.

In view of the fact that these two sites are so different in geologic type and in methods of mining and disposal, we might expect surface characteristics to vary somewhat. By comparison of tables 11 and 12, we find this to be the case for some of the spoil characteristics. It is

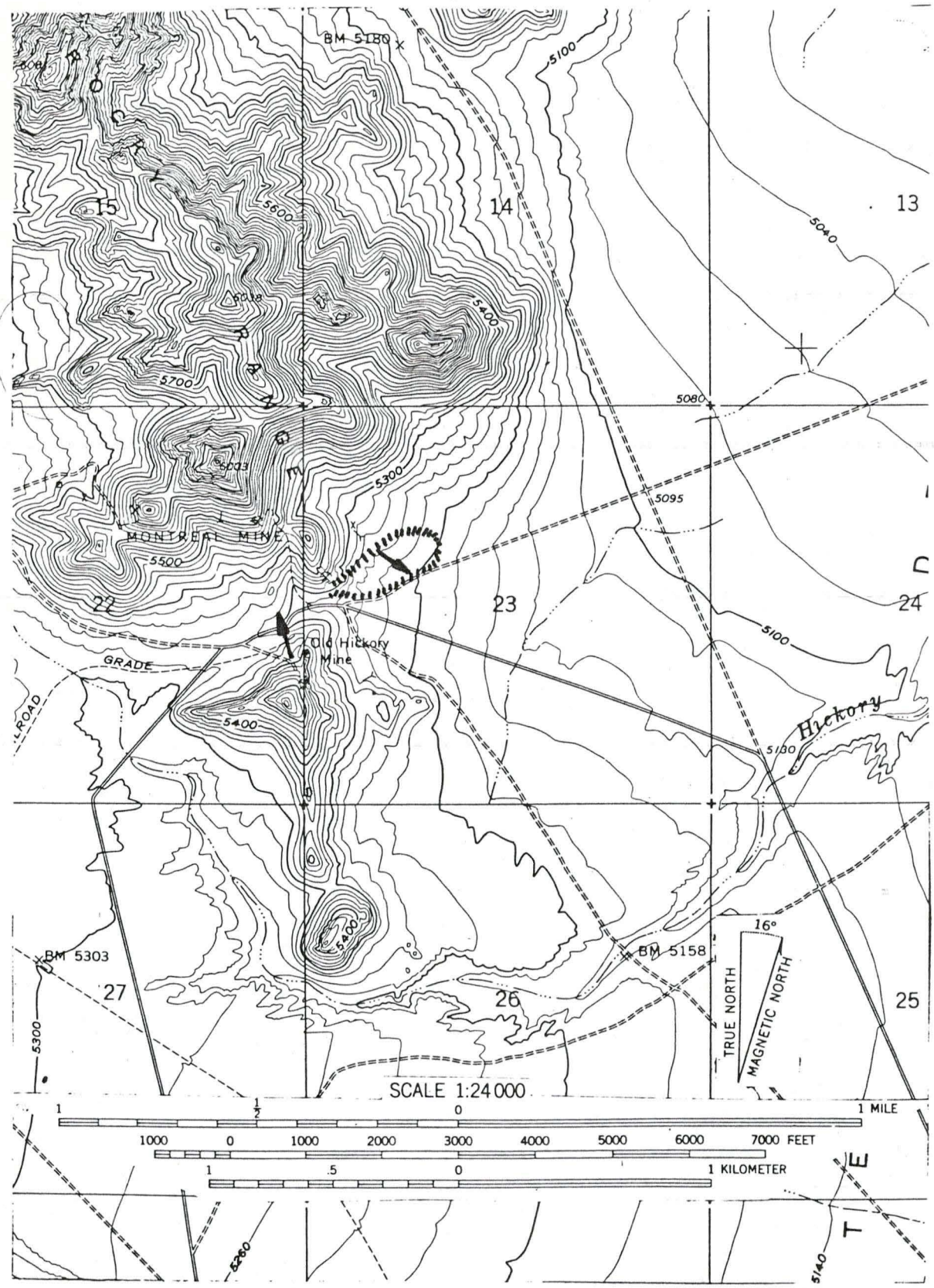


Figure 32. Map of the Rocky Range area near Milford, Utah. Reprint, U.S.G.S. topographic, 7.5 minute quadrangle.

Figure 33. Old Hickory Mine: top, distant view of shaft mine with head frame; bottom, sampled spoils in left foreground, Bowana Mine in background.

Table 11 Selected characteristics of site I, Milford, Old Hickory Mine.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
5 miles N.W. of Milford, Utah	5,400	Rocky	10

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Tertiary quartz monzonite Talisman Formation	Quartz monzonite Quartzite Limestone Skarn	8.39

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
65.1	33.3	Artemisia

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
N.W.	74	75 ft.	7.4	3.2

[a] Baetcke, 1969. Stratigraphy of the Star Range and reconnaissance study of three selected mines; J. A. Whelan, 1974, personal communication; and field inspection.

[b] U.S. Dept. of Commerce, Weather Bureau, 1960. Data for Milford, Utah.

[c] U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 11 Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
2.5	60	.3	40.6

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
58	sandy loam	1.90

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
28	10,655	6.71

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
5.26	1,482	5.05

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 11. Continued

Chemical quality of runoff[f]		
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)	
	water applied	runoff
3.40	3.3	3.5

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.6	7.8	1200	1200

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

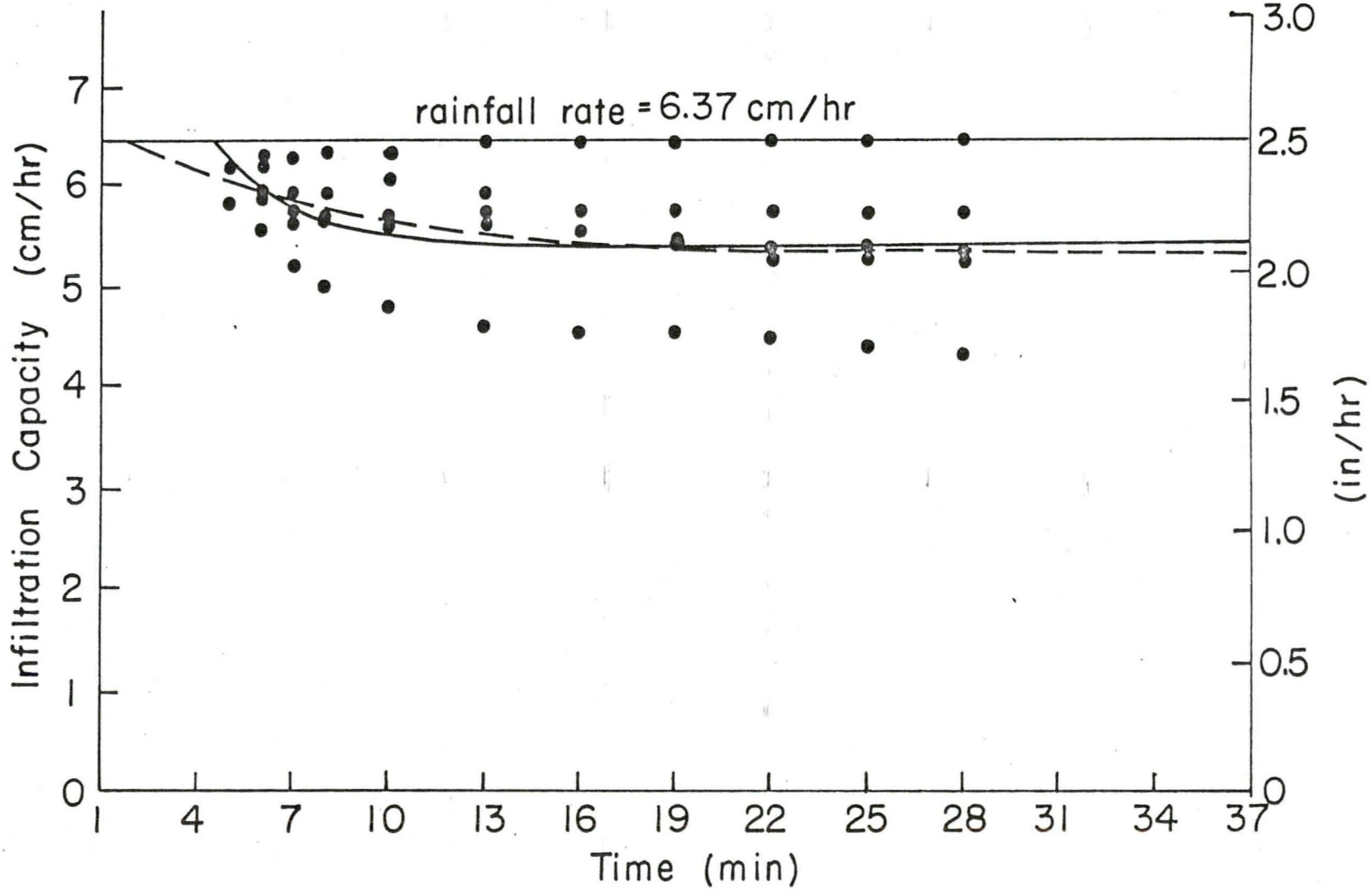


Figure 34. Infiltration curve for the spoils at Old Hickory Mine.

Figure 35. Bowana Mine: top, large spoils pile sampled; bottom, sampling area on flat.

Table 12Selected characteristics of site I, Milford, Bowana Copper Mine.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
5 miles N.W. of Milford, Utah	5,300	Rocky	50

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Tertiary quartz monzonite Toroweap formation Kaibab-Plympton formation	Quartz monzonite Skarn Limestone	8.39

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
65.1	33.3	Artemisia

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
S.E.	5	700 ft.	7.9	.8

[a]Baetcke, 1969. Stratigraphy of the Star Range and reconnaissance study of three selected mines; J. A. Whelam, 1974, personal communication; and field inspection.

[b]U.S. Dept. of Commerce, Weather Bureau, 1960. Data for Milford, Utah.

[c]U.S.U. Soil, Plant and Water Analysis Laboratory

Table 12. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
1.6	21	.2	3.9

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
62	sandy loam	1.71

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
21	6,801	8.00

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
3.18	5,336	1.59

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 12. Continued

Chemical quality of runoff[f]			
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)		
	water applied	runoff	
.30	3.3	3.3	

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.6	7.8	1200	1500

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

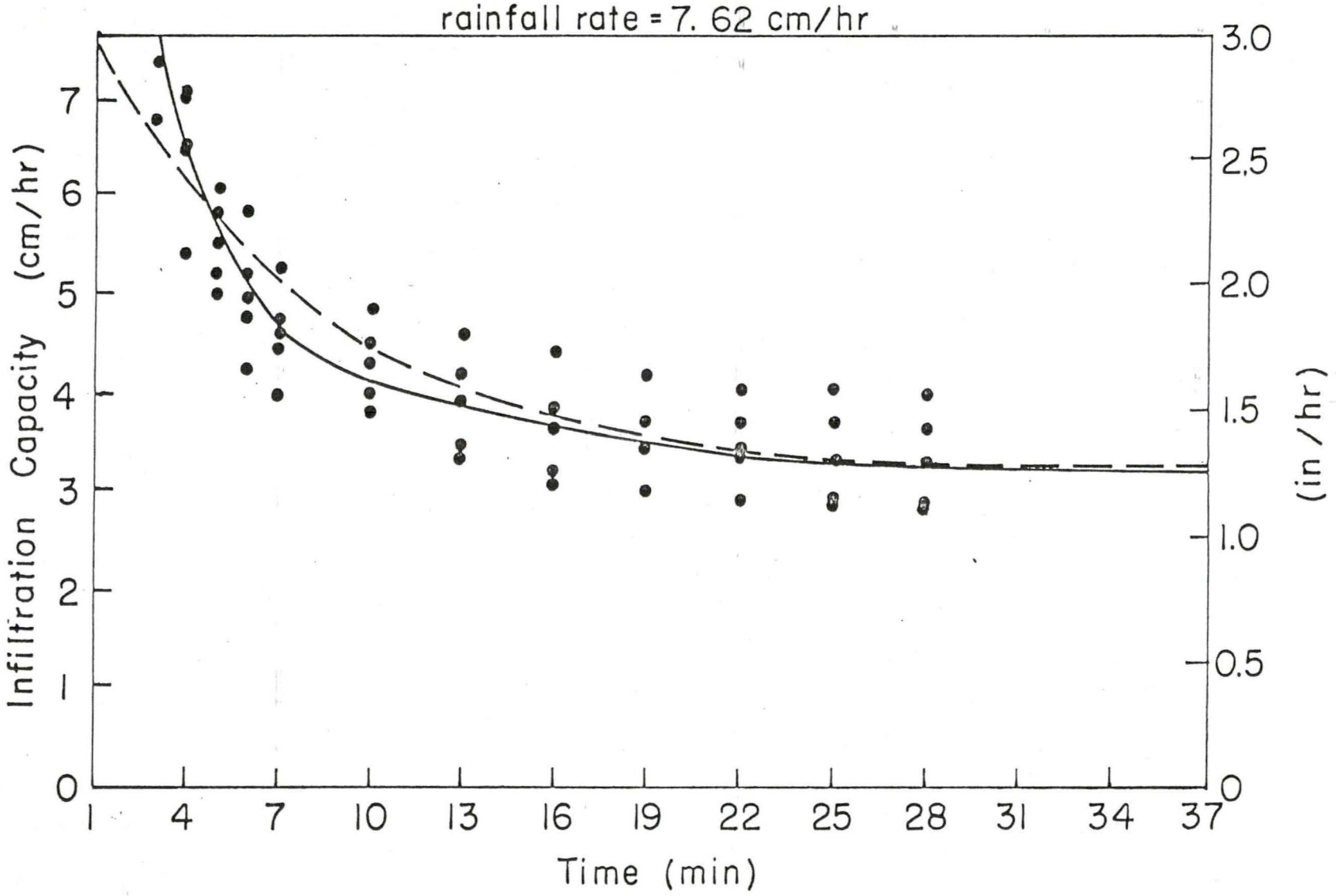


Figure 36. Infiltration curves for the spoils at Bowana Mine.

interesting to note the large differences in surface hydrology (figures 34 and 36) between these two sites, especially when it is realized that they have the same overall texture.

J. Rattlesnake Ranch

The Rattlesnake Mine is located 6 miles west of La Sal, Utah. Uranium and vanadium were mined at this site from gray, white and light red lenticular fine-grained sandstones and red and green mudstones of the Salt Wash Member of the Morrison Formation (Johnson and Thordarson, 1966). The open pit and shaft mining methods were both employed. At present the mine is inactive and historical data was not obtained.

Spoils consist of a loose mixture of pebbles, chips of petrified wood, and fines. The texture of the fines is clay loam according to the Utah State University Soil, Plant and Water Analysis Laboratory (table 13). Surface infiltration seems quite high for such texture, but the presence of pebbles and chips in a rather loose mass probably accounts for the high intake rate.

The loose packing of the spoils is also evident by the way vegetation only grows on those materials where slopes are not steep. On steep slopes, the spoils are too mobile.

K. Fry Canyon

The mine sampled at Fry Canyon Station is located near the head of Fry Canyon at what was called Ears Prospects in 1964 (Thaden, Trites, and Finnell, 1964). Uranium is shaft mined in the Shinarump Member of the Chinle Formation. These rocks form lenses of interstratified sandstone, siltstone, and conglomerate that fill channels cut into the top of the

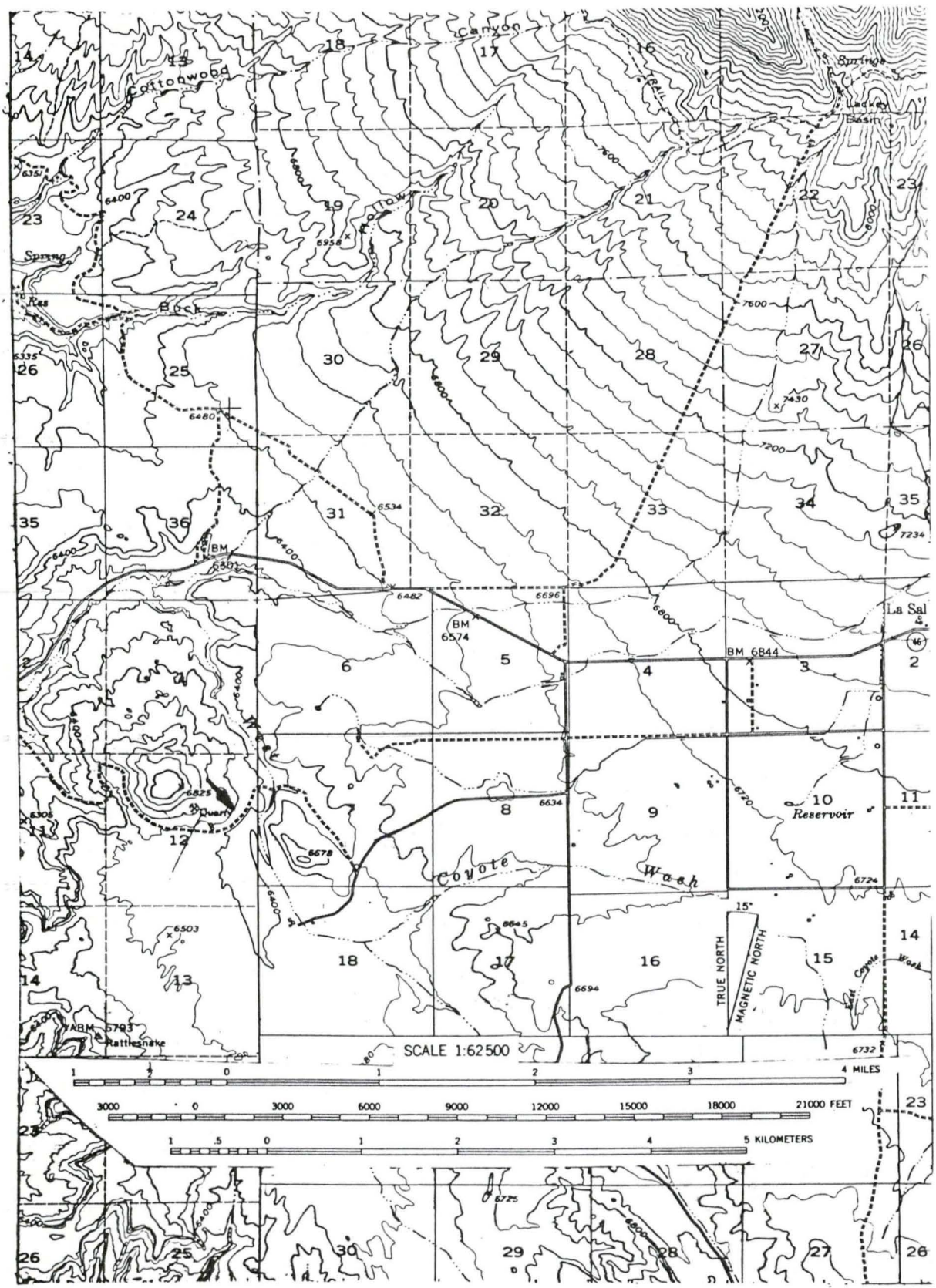


Figure 37. Map of Rattlesnake Ranch area near LaSal, Utah. Reprint, U.S.G.S. topographic, 15 minute quadrangle.

Figure 38. Rattlesnake Ranch: top, distant view of uranium mine; bottom, sampling area showing spoils made up of materials excavated from the Brushy Basin member.

Table13 Selected characteristics of site J, Rattlesnake Ranch.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
5 miles S.W. of La Sal, Utah	6,600	Big Indian	50

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Salt Wash member of Morrison Formation	Sandstone Mudstone	12.41

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
59.1°F	32.9°F	Pinyon Juniper

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
S.E.	61	250 ft.	7.8	.5

[a]Johnson and Thordarson, 1966. Uranium deposits of the Moab, Monticello, White Canyon, and Monument Valley districts, Utah; and field inspection.

[b]U.S. Dept. of Commerce, Weather Bureau, 1960. Data for LaSal, Utah.

[c]U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 13 Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
.3	.1	.3	< .1

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
21	clay loam	1.30

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
65	11,627	24.56

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
5.99	510	10.9

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 13 Continued

Chemical quality of runoff[f]		
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)	
	water applied	runoff
21.4	7.4	7.4

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.7	7.7	400	450

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

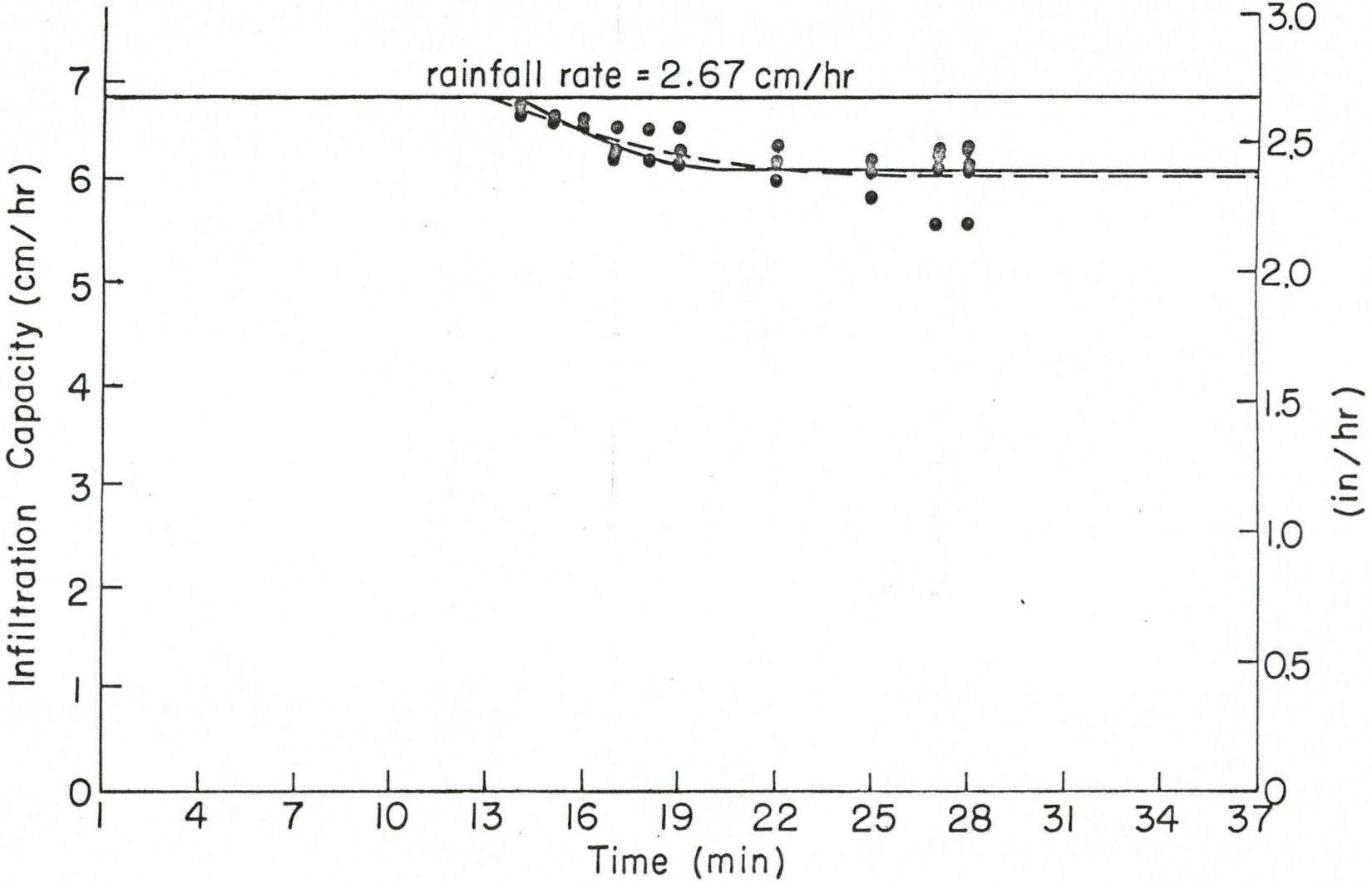


Figure 39. Infiltration curve for the spoils at Rattlesnake Ranch.

Moenkope Formation. Uraninite, a mineral that replaces petrified wood in the deposits, is the chief ore.

The Shinarump rocks outcrop on the faces of steep slopes in the Fry Canyon area. The mine portals are thus situated in such a position that spoils delivered to the entrance are side cast down the slopes forming long, narrow, steep dumps in front of the mines (figure 41).

The spoils contain small amounts of pyrite and copper minerals. Runoff waters showed a slight decrease in pH over the tap water applied.

L. White Canyon

The Happy Jack Mine is the largest known uranium operation in White Canyon (Thaden, Trites, and Finnell, 1964). It is located in White Canyon about 5 miles east of Hite Marina on Lake Powell (figure 43). The mine produced uranium ores as early as 1949. Major activity in the area, however, did not begin until after extensive exploration work in the early 1950s. In recent years mining has been intermittent with only minor production at the time of this report.

The spoils at Happy Jack Mine are very similar to those at Fry Canyon (20 miles east). They are derived from the same type rocks of the shinarump member and were extracted, moved, and disposed of in a similar fashion. Spoils at other mines visited in White Canyon appear to have the same characteristics.

Two samples of surface hydrology were taken at the Happy Jack Mine, one for spoils slopes and the other for a large flat located near the entrances to the mine. A comparison of these two samples (table 15) shows that spoils on the flat have been compacted (higher bulk density) and infiltration rates correspondingly reduced. These characteristics are similar to what has been previously described in sites A and G.

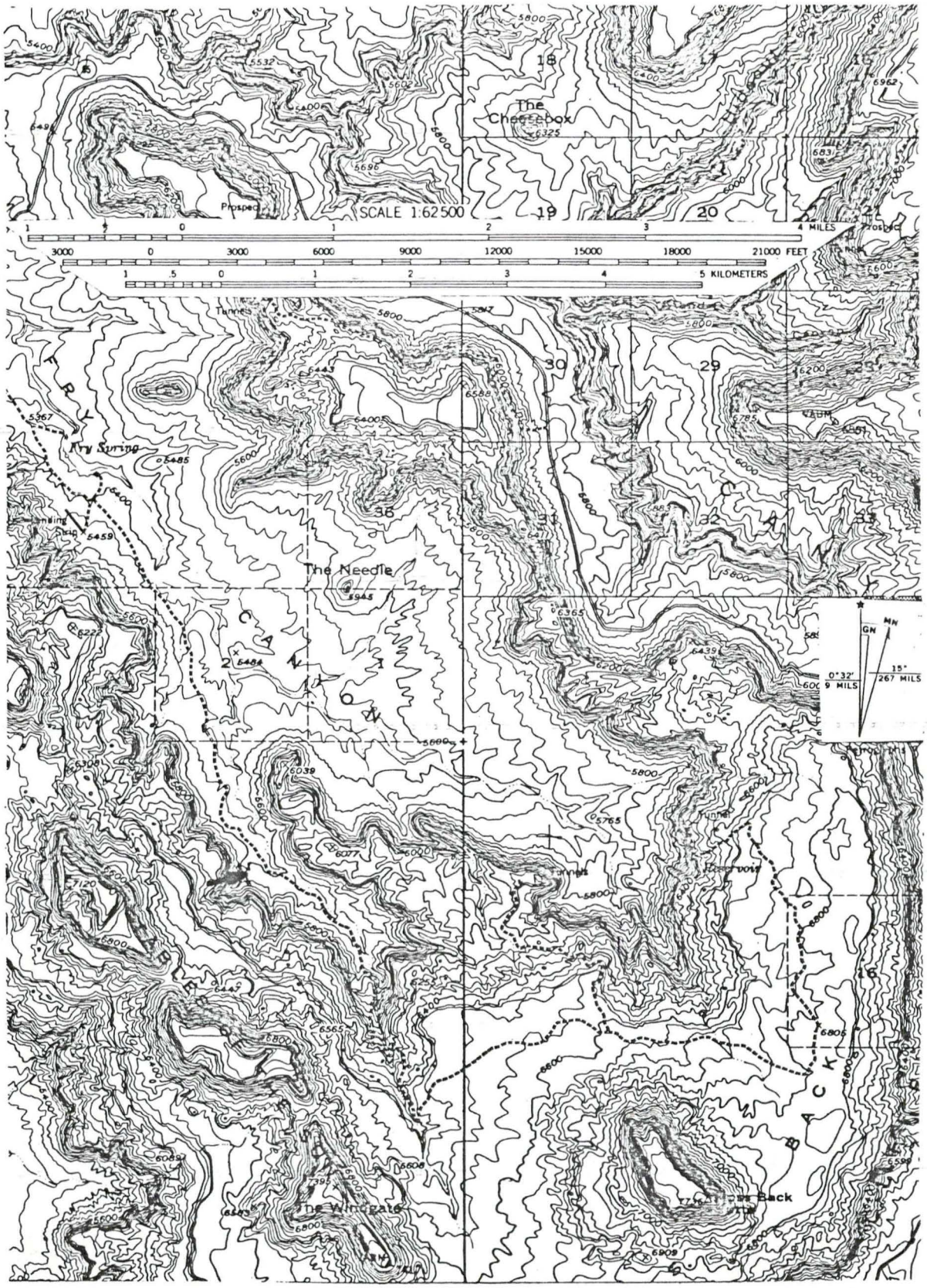


Figure 40. Map of the Fry Canyon area Utah. Reprint, U.S.G.S. topographic, 15 minute quadrangle.

Figure 41. Fry Canyon: top, distant view; bottom, sampling area on steep slope.

Table14.Selected characteristics of site K, Fry Canyon.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
70 miles west of Blanding, Utah	6,200	White Canyon	4

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Shiharump member of Chinle formation	Sandstone Siltstone	12.27

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
63.5	35.2	Pinyon Juniper

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
N.E.	88	350 ft.	6.9	2.5

[a]Thaden, Trites and Finnell, 1964. Geology and ore deposits of the White Canyon area, San Juan and Garfield Counties, Utah; and field inspection.

[b]U.S. Dept. of Commerce, Weather Bureau, 1952. Data for Blanding, Utah.

[c]U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 14. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
3.6	.7	.1	1.9

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
22	silt loam	1.47

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
28	7,346	7.87

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
2.72	4,791	118.4

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 14. Continued

Chemical quality of runoff[f]					
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)				
	water applied	runoff			
24.7	7.8	13.8			
Chemical quality of runoff (cont.)					
pH			Salinity (ppm)		
water applied	runoff		water applied	runoff	
7.7	7.3		400	2,850	

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

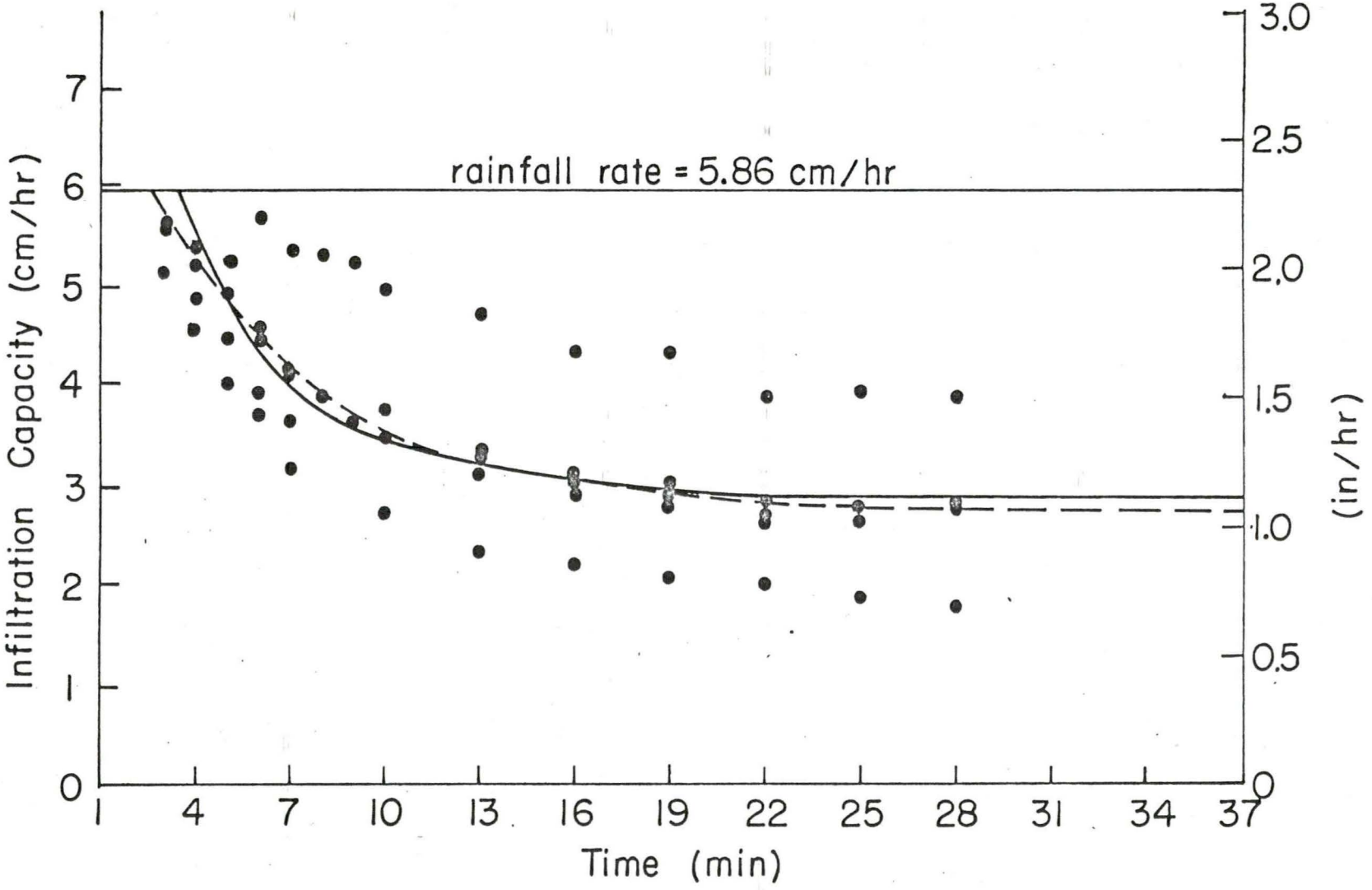


Figure 42. Infiltration curve for the spoils at Fry Canyon.

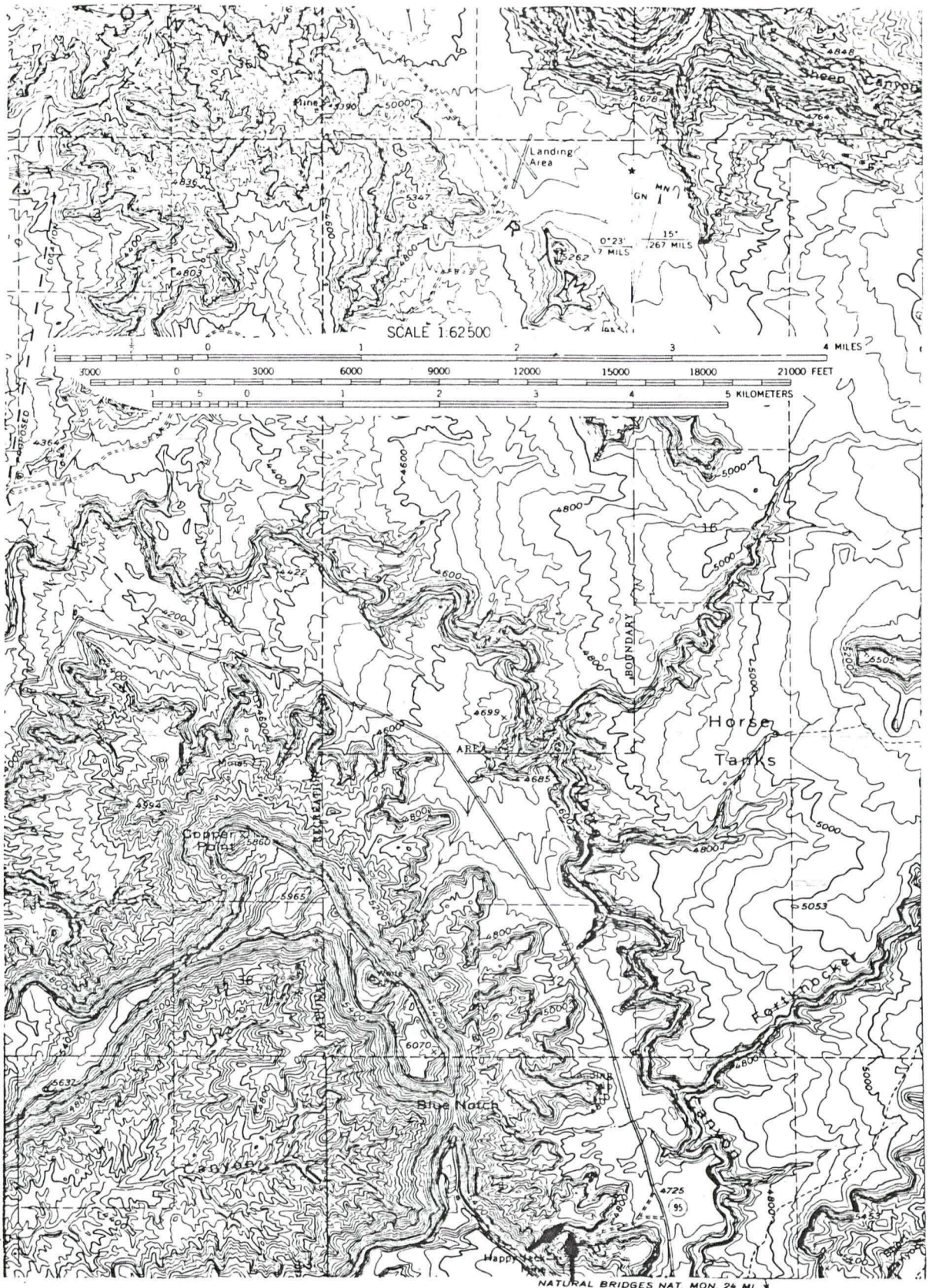


Figure 43. Map of the White Canyon area and Happy Jack Mine. Reprint, U S G.S. topographic 15 minute quadrangle.

Figure 44. Happy Jack Uranium Mine: top, distant view; bottom, sampling area showing creep on oversteepened slope.

Table 15. Selected characteristics of site L, White Canyon.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
76 miles west of Blanding, Utah	5,000	White Canyon	10

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Shinarump Member of Chinle Formation	Sandstone Siltstone	12.27

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
74.2	46.3	Mt. Mahogany

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
N (slope) N.E.(flat)	68 (slope) 7 (flat)	90 ft. (slope) 250 ft. (flat)	7.6	2.9

[a] Thaden, Trites and Finnell, 1964. Geology and ore deposits of the White Canyon area, San Juan and Garfield Counties, Utah; and field inspection.

[b] U.S. Dept. of Commerce, Weather Bureau (1952 and 1960). Data for Blanding (1952) and Hite, Utah (1960).

[c] U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 15. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
3.2	.4	.1	35.2

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
60	Silt loam	1.35 (slope) 1.62 (flat)

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
18 (slope) 30 (flat)	7,549 (slope) 6,404 (flat)	8.84 (slope) 9.50 (flat)

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
3.07 (slope) 2.74 (flat)	4,587 (slope) 5,733 (flat)	145.5 (slope) 22.1 (flat)

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 15. Continued

Chemical quality of runoff[f]		
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)	
	water applied	runoff
31.7 (slope) 3.9 (flat)	7.8	8.2

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.7	7.9	400	400

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

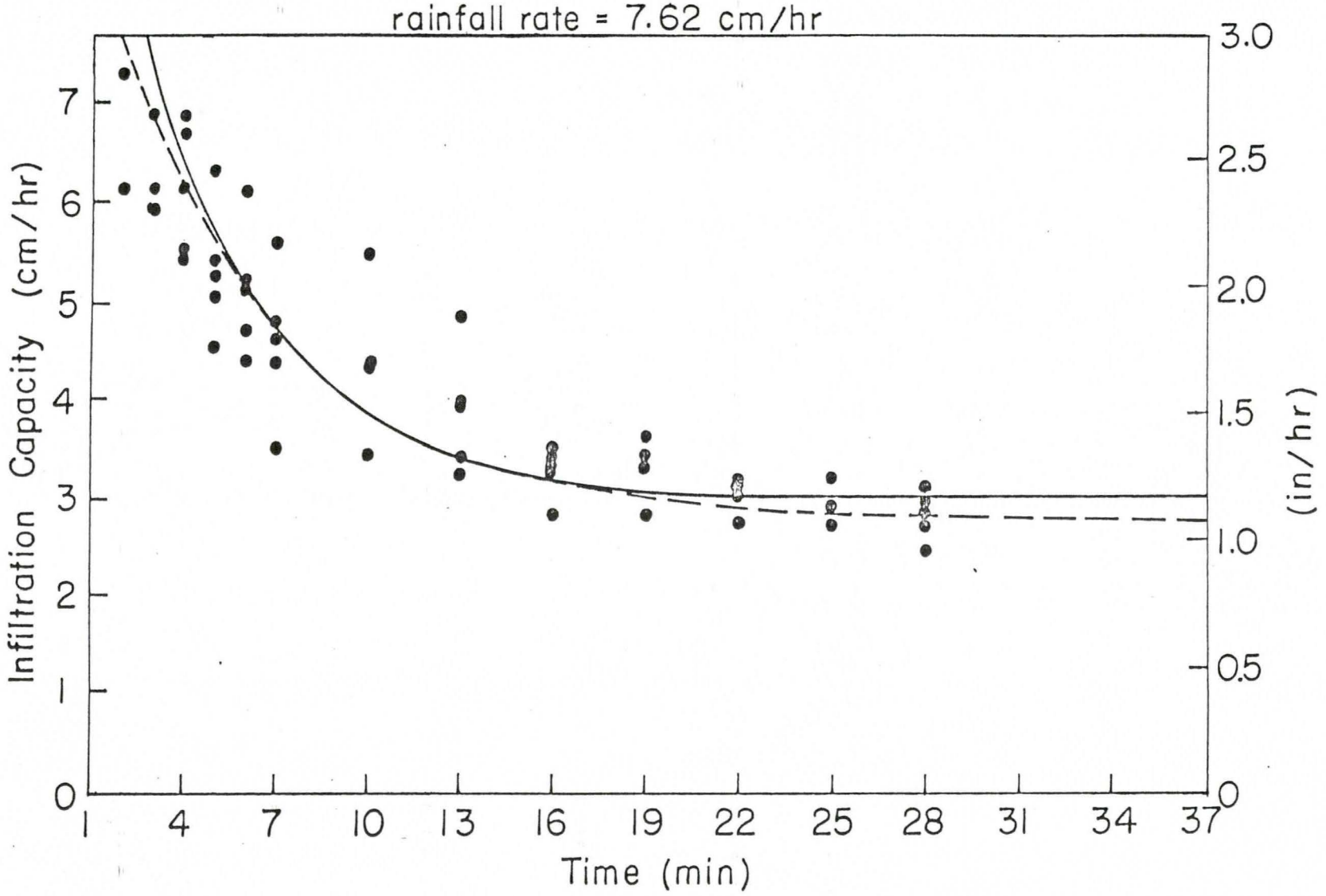


Figure 45. Infiltration curve for the spoils at Happy Jack Mine (flat).

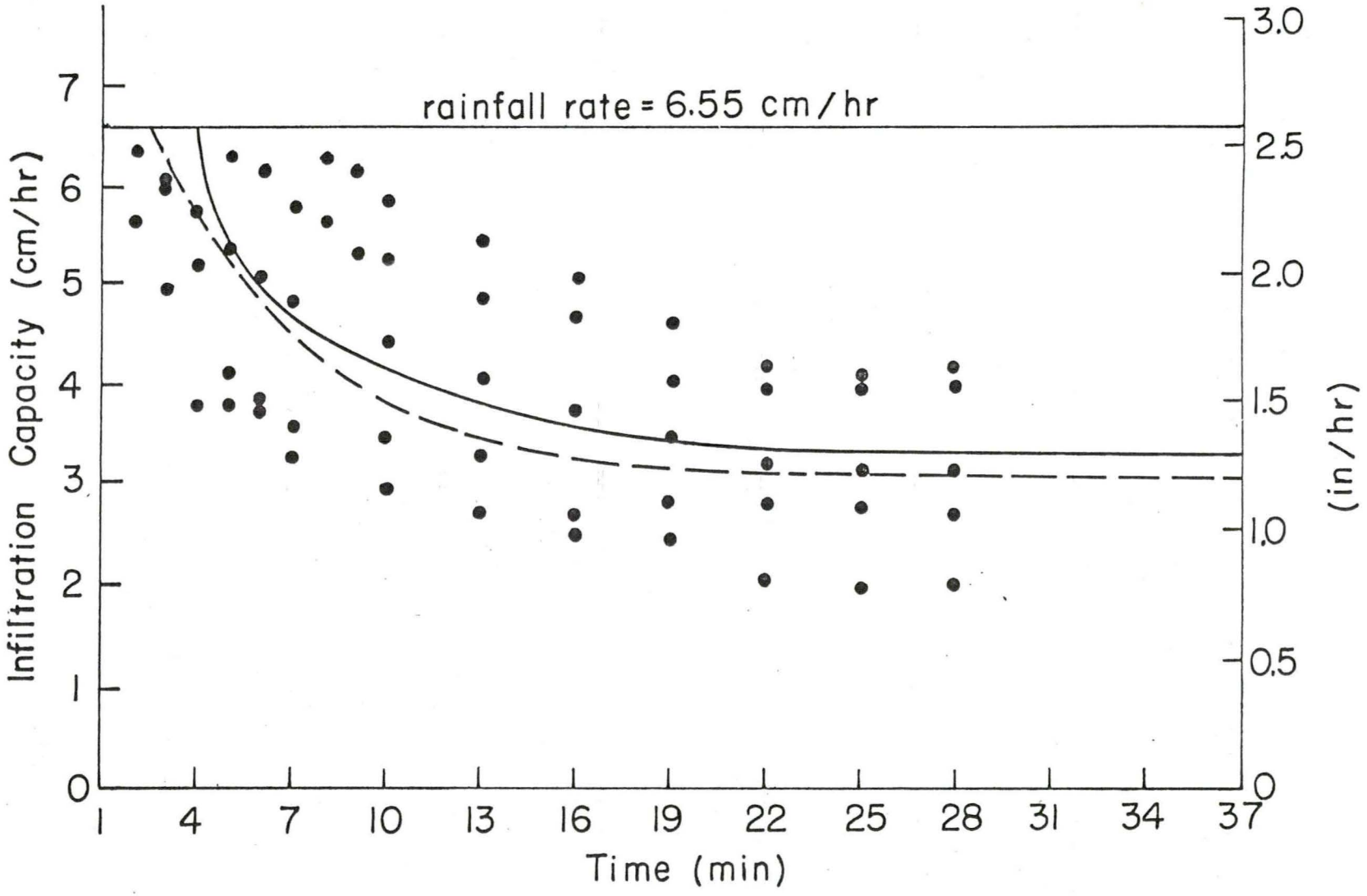


Figure 46. Infiltration curve for the spoils at Happy Jack Mine (slope).

The surface hydrology and erosion parameters measured on the slope compare favorably well with those measured at Fry Canyon.

M. Dutchman Flat

The Dutchman Mine in American Fork Canyon (see figure 47) was discovered in 1872. It was mined intermittently for about 40 years before Fissures Exploration Company built a mill at the site in 1917. At this time production of lead and silver was stepped up. The mill was soon thereafter dismantled and ores were shipped to Pacific for milling (Calkins and Butler, 1943).

The spoils are derived from shaft workings in the Deseret and Gardison Limestone Formations. These rocks, where altered, are made up of shale and soft clay. The spoils consist of a combination of these rocks with scattered areas of one rock type dominating over the other. Several areas observed contained small pockets of clay. The variability in texture in these spoils (table 16) is a result of the wide distribution of petrologic types in the spoils surface.

These spoils are characterized by a very hard surface only one-half inch deep. As a consequence, surface hydrology is fairly uniform across the dump (figure 49).

N. Alta

Several spoils were sampled in the Alta area near Salt Lake City. Two samples were taken on spoils from the Emma Mine and one at the Bel Vega Mine. These two mines will be discussed separately.

The Emma Mine was discovered in 1868 and mining for lead and silver began in 1870. The mine was abandoned in 1876 because of the expense involved in pumping mine waters out of the deep shaft. In 1917, a new ore body was located, the mine was dewatered and ores were shipped to the

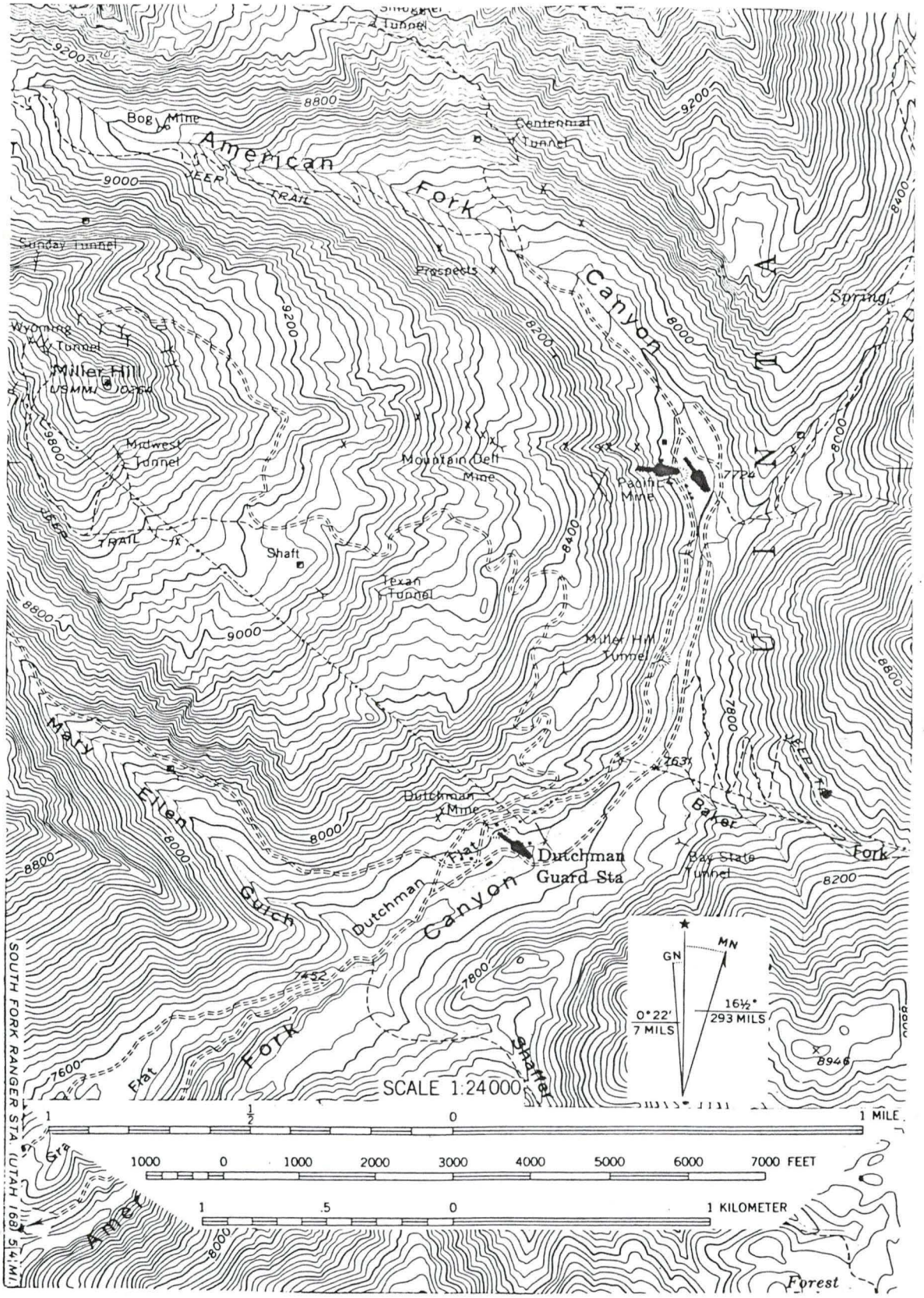


Figure 47. Map of Dutchman Mine in American Fork Canyon. Reprint, U.S.G.S. topographic, 7.5 minute quadrangle.

Figure 48. Dutchman Mine: top, sampling area for slopes with remnants of old mill in the foreground; bottom, closeup view of the same spoils.

Table16.Selected characteristics of site M, Dutchman Flat.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
25 miles N.E. of American Fork, Utah	7,600	American Fork	2

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Deseret and Gardison limestones	Limestone Shale Clay	54.47

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
49.5	23.5	Aspen

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
S.E.	61	75 ft.	6.8	2.3

[a]Baker, Calkins, Crittenden, 1966. Geologic map of the Brighton Quadrangle, Utah; and field inspection.

[b]U.S. Dept. of Commerce, Weather Bureau, 1960. Data for Alta, Utah and Brighton, Utah.

[c]U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 16. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
13.0	.8	.1	8.6

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
26	variable: silt loam to clay	1.46

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
variable: 32 to 59	4,934	5.49

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
2.01	7,203	205.6

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table16. Continued

Chemical quality of runoff[f]		
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)	
	water applied	runoff
28.5	2.1	5.9

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.8	7.0	< 100	200

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

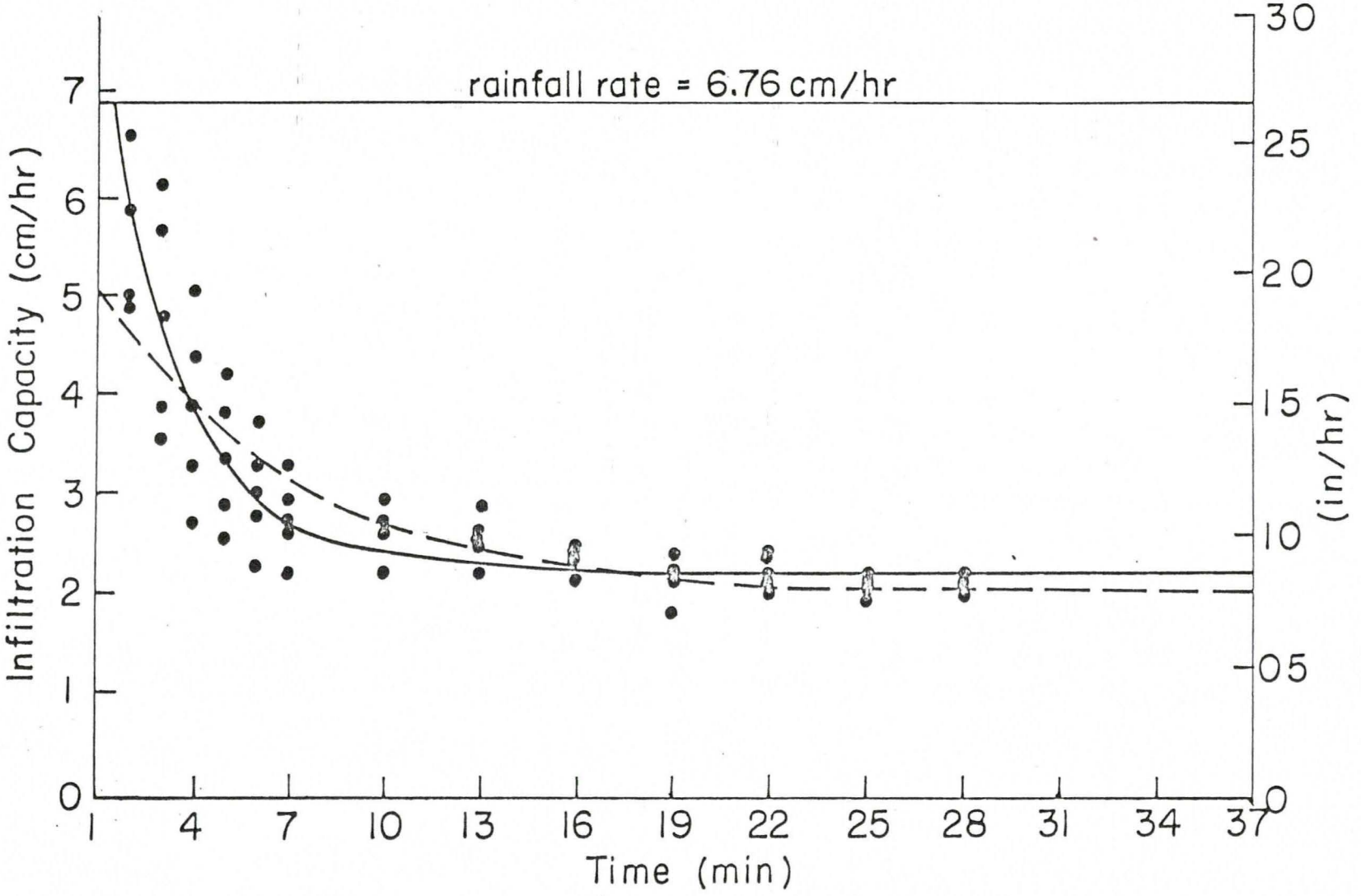


Figure 49. Infiltration curve for the spoils at Dutchman Mine.

U.S. Smelting, Refining and Mining Company Smelter at Midvale, Utah. The mine was partly active in the 1940s and today is inactive (Baker, Calkins, Crittenden, 1966).

The spoils derived from the Emma Mine are scattered in several piles on the north side of Little Cottonwood Canyon (figure 51). These spoils were derived from limestones that have been bleached by metamorphism and therefore appear to be tailings when first examined. One of the Emma Mine dumps is located adjacent to the canyon road. This dump has been graded off and is used as a parking lot for recreationists. In wintertime a mixture of salt and sand is deposited on the parking lot by the state highway department in maintaining a snow-free surface. This salt eventually ends up on the surface of the slopes of the dump where erosion potentials are higher.

In tables 17 and 18, we find that the characteristics of the surface materials representing both Emma Mine dumps are somewhat alike. One significant exception is that of salinity levels measured in the material. Salinity is 18 times as great on the parking lot. Sodium may be an important constituent of this salt since its average concentration (water-soluble sodium) is 8 times as great on the parking lot.

Major hydrologic differences were observed between the two sampled Emma Mine sites. Approximately two times as much water infiltrated the low-sodium spoils. The reduction in infiltration on the parking lot might possibly be caused by a sodic condition in the material. If there is an excess of exchangeable sodium in these spoils, the effect is to disperse clay particles which in turn causes the formation of a dense, impenetrable surface crust (Hausenbuiller, 1972). As a consequence, infiltration rates are lowered.

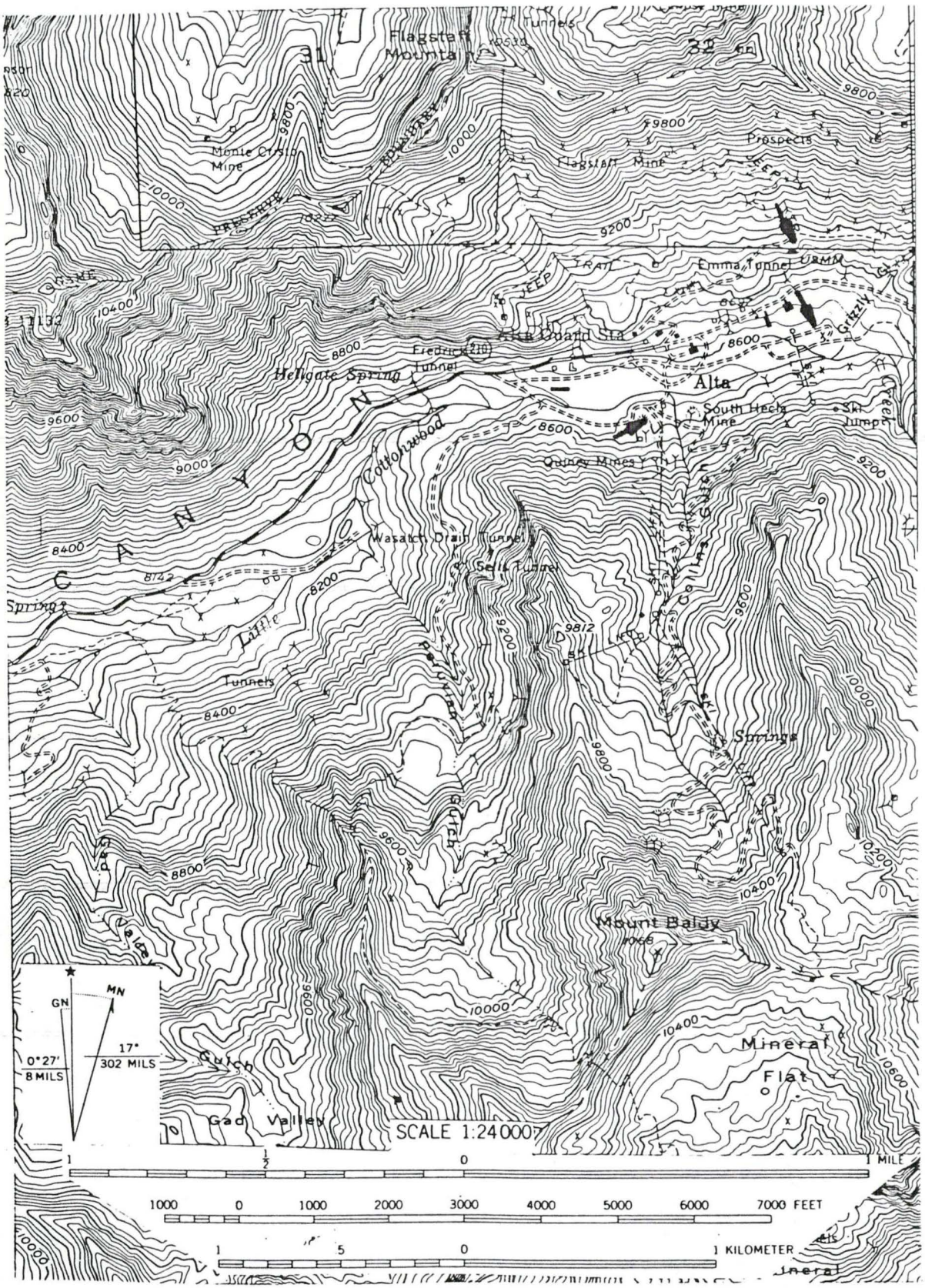


Figure 50. Map of the Alta area, Utah. Reprint, U.S.G.S. topographic, 7.5 minute quadrangle.

Figure 51. Alta: top, overall view showing Bel Vega Mine just right of center; bottom, Emma Mine spoils used for parking.

Figure 51. (Continued) Alta: top, Bel Vega Mine spoils showing attempted stabilization; bottom, erosion on upper Emma Mine spoils.

Table 17. Selected characteristics of site N1, Alta, Emma Mine.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
20 miles S.E. of Salt Lake City, Utah	9,000	Big and Little Cottonwood	2

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Madison limestone	Limestones and altered limestones	54.47

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
49.5	23.5	fir aspen

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
S	64	90 ft.	7.8	.3

[a] Baker, Calkins, Crittenden, 1966. Geologic map of the Brighton Quadrangle, Utah; and field inspection.

[b] U.S. Dept. of Commerce, Weather Bureau, 1960. Data for Alta, Utah and Brighton, Utah.

[c] U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 17. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
2.3	.21	< .1	.9

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
52	sandy loam	1.90

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
22	10,711	9.63

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
4.32	1,426	35.9

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 17. Continued

Chemical quality of runoff[f]		
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)	
	water applied	runoff
25.2	3.9	4.0

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
8.0	8.0	1300	1300

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

Table18.Selected characteristics of site N2, Alta, Parking lot.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
20 miles S.E. of Salt Lake City, Utah	8,700	Big and Little Cottonwood	1

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Madison limestone	Limestones and altered limestones	54.47

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
49.5	23.5	Fir Aspen

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
S	74	75 ft.	7.6	5.4

[a]Baker, Calkins, Crittenden, 1966. Geologic map of the Brighton Quadrangle, Utah; and field inspection.

[b]U.S. Dept. of Commerce, Weather Bureau, 1960. Data for Alta, Utah and Brighton, Utah.

[c]U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 18. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
3.6	.46	.8	31.0

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
47	sandy loam	1.90

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
21	5,458	6.12

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
2.01	6,680	246.8

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table18. Continued

Chemical quality of runoff[f]		
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)	
	water applied	runoff
37.0	3.9	8.3

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
8.0	7.8	1300	2,500 (composite) 4,500 (east side)

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

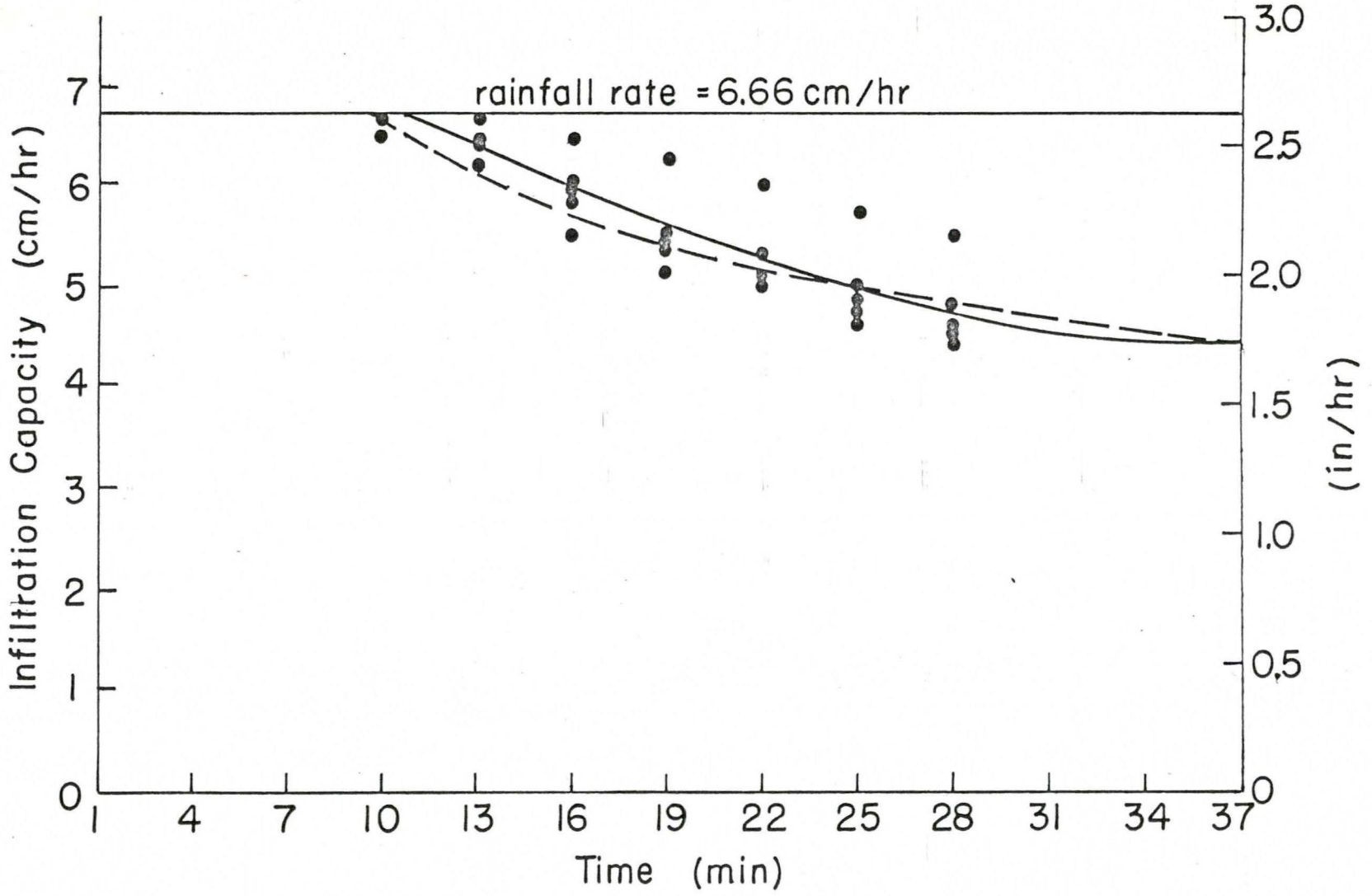


Figure 52. Infiltration curve for the spoils at Emma Mine.

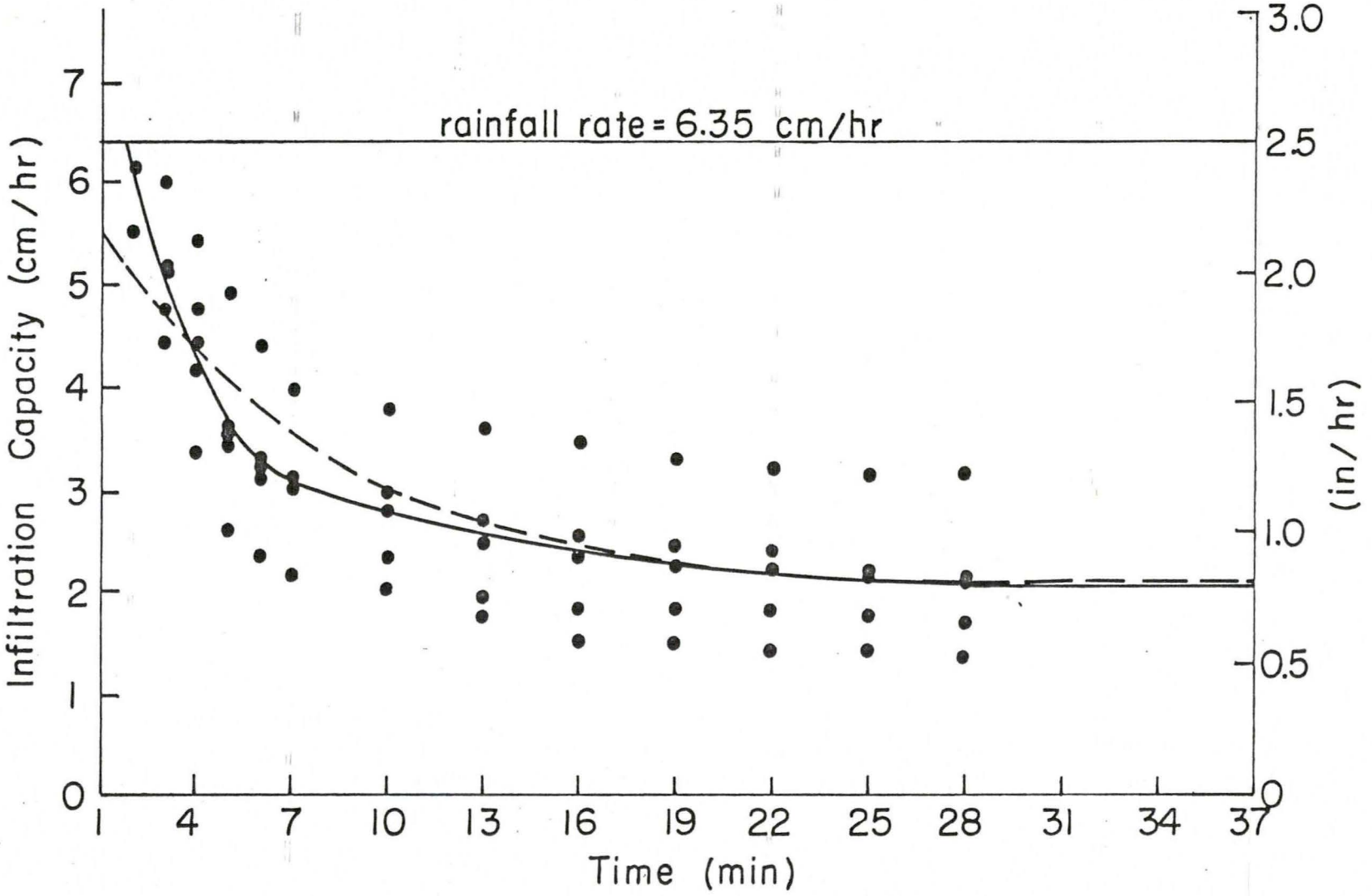


Figure 53. Infiltration curve for the tailings at Emma Mine (parking lot).

Table19.Selected characteristics of site N3, Alta, Bel-Vega Mine.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
20 miles S.E. of Salt Lake City, Utah	8,600	Big and Little Cottonwood	1

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Cambrian quartzites	Quartzite limestone granodiorite	54.47

Climate[b]			
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone	
49.5	23.5	Fir	Aspen

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
N.E.	79	40 ft.	7.4	2.2

[a]Baker, Calkins, Crittenden, 1966. Geologic map of the Brighton Quadrangel, Utah; and field inspection.

[b]U.S. Dept. of Commerce, Weather Bureau, 1960. Data for Alta, Utah and Brighton, Utah.

[c]U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 19 Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
9.2	.57	< .1	27.1

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
63	silt loam	1.71

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
28	8,193	6.30

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
3.25	3,944	36.6

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 19. Continued

Chemical quality of runoff[f]		
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)	
	water applied	runoff
9.3	3.9	4.7

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
8.0	7.9	1300	1500

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

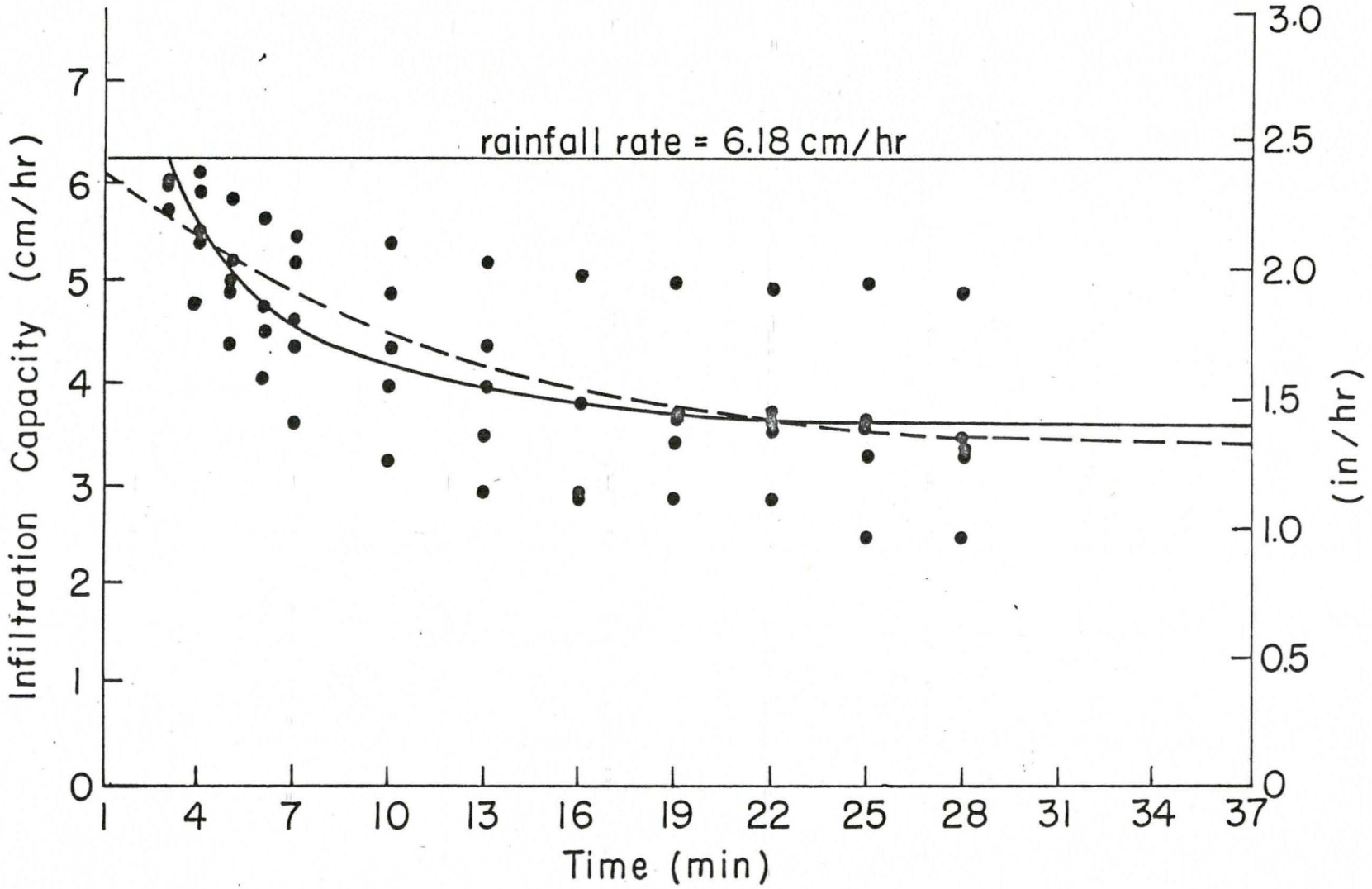


Figure 54. Infiltration curve for the spoils at Bel Vega Mine.

The Bel Vega Mine is located adjacent to the Alta Lodge in the center of the Alta Ski resort (figure 50). Spoils from this mine were deposited at the mine portal and consist of fragments of limestone, granodiorite, and quartzite mixed with fines. Other characteristics are identified in table 19.

O. Pacific

The Pacific Mine is located in upper American Fork Canyon just three miles above Dutchman Flat. It was mined for lead and silver during the early 1900s by the Pacific Gold Mining and Milling Company. In 1916 a mill was erected at the site for concentrating ores which could, after treatment, be delivered to the smelter for $40 a ton (Calkins and Butler, 1943).

Spoils and tailings were derived from shaft mine workings in the Tintic Quartzite. They are sandy white deposits situated adjacent to a small stream (figure 56).

A flume carried tailings out of the mill to a large pond which is now being eroded by mine waters. Infiltration characteristics on the pond were found to be quite different from those measured on the spoils (table 20). Surface hydrology varies from one point to another on the pond as a result of the textural characteristics associated with a complex system of stratified leases that form the surface layers of the deposit. Well sorted fine sandy-grained materials are easily lifted by wind currents and concentrated in certain areas of the dump. These infilter water at very high rates.

Surface hydrology on the spoils is much more uniform as shown by tests made from one plot to another. Infiltration rates were somewhat lower.

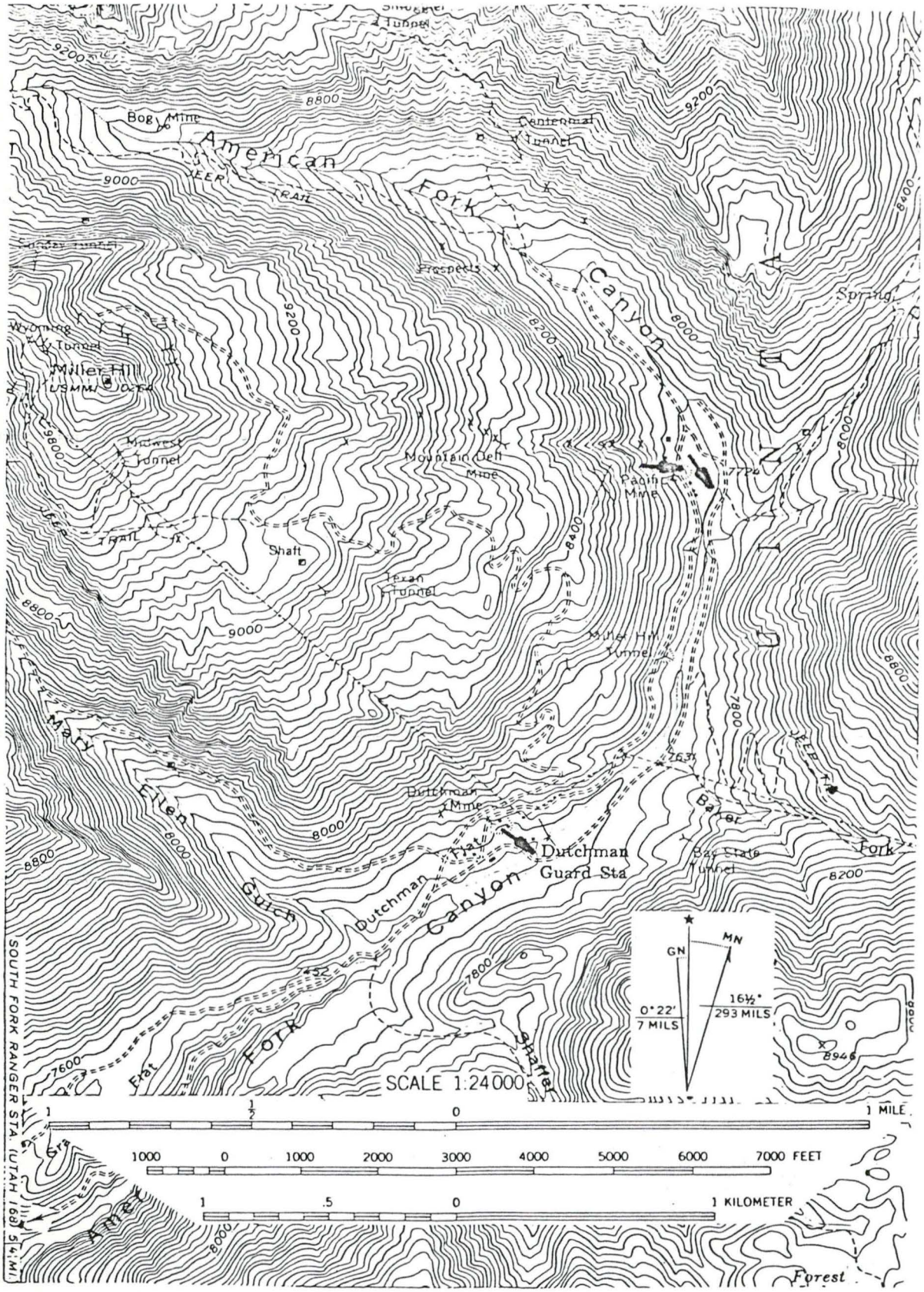


Figure 55. Map of Pacific Mine in American Fork Canyon. Reprint, U.S.G.S. topographic 7.5 minute quadrangle.

Figure 56. Pacific Mine: top, spoils or tailings; bottom, tailings pond with stream at left.

Table20.Selected characteristics of site O, Pacific.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
25 miles N.E. of American Fork, Utah	7,800	American Fork	3

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Tintic Quartzite	quartzite, limestone	54.47

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
49.5	23.5	Fir Aspen

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
S.W. (tailings)	11 (tailings)	175 ft. (tailings)	5.2 (tailings)	3.5 (tailings)
E. (spoils)	65 (spoils)	65 ft. (spoils)	6.2 (spoils)	.4 (spoils)

[a]Calkins and Butler, 1943. Geology and ore deposits of the Cottonwood-American Fork area, Utah; and field inspection.

[b]U.S. Dept. of Commerce, Weather Bureau, 1960. Data for Alta, Utah and Brighton, Utah

[c]U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 20. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
4.2 (tailings)	.8 (tailings)	<.1 (tailings)	.7 (tailings)
3.3 (spoils)	.3 (spoils)	<.1 (spoils)	.7 (spoils)

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
45 (tailings)	sandy loam (tailings)	1.67 (tailings)
57 (spoils)	sandy loam (spoils)	1.77 (spoils)

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
23 (tailings)	7,297 (tailings)	6.63 (tailings)
19 (spoils)	4,673 (spoils)	6.81 (spoils)

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
4.09 (tailings)	4,841 (tailings)	8.43 (tailings)
3.25 (spoils)	7,460 (spoils)	115.93 (spoils)

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table20. Continued

Chemical quality of runoff[f]			
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)		
	water applied	runoff	
1.7 (tailings)	2.1 (tailings)	2.1 (tailings)	
15.5 (spoils)	2.1 (spoils)	3.2 (spoils)	

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.8 (tailings)	7.7 (tailings)	< 100 (tailings)	<100 (tailings)
7.8 (spoils)	7.1 (spoils)	< 100 (spoils)	<100 (spoils)

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

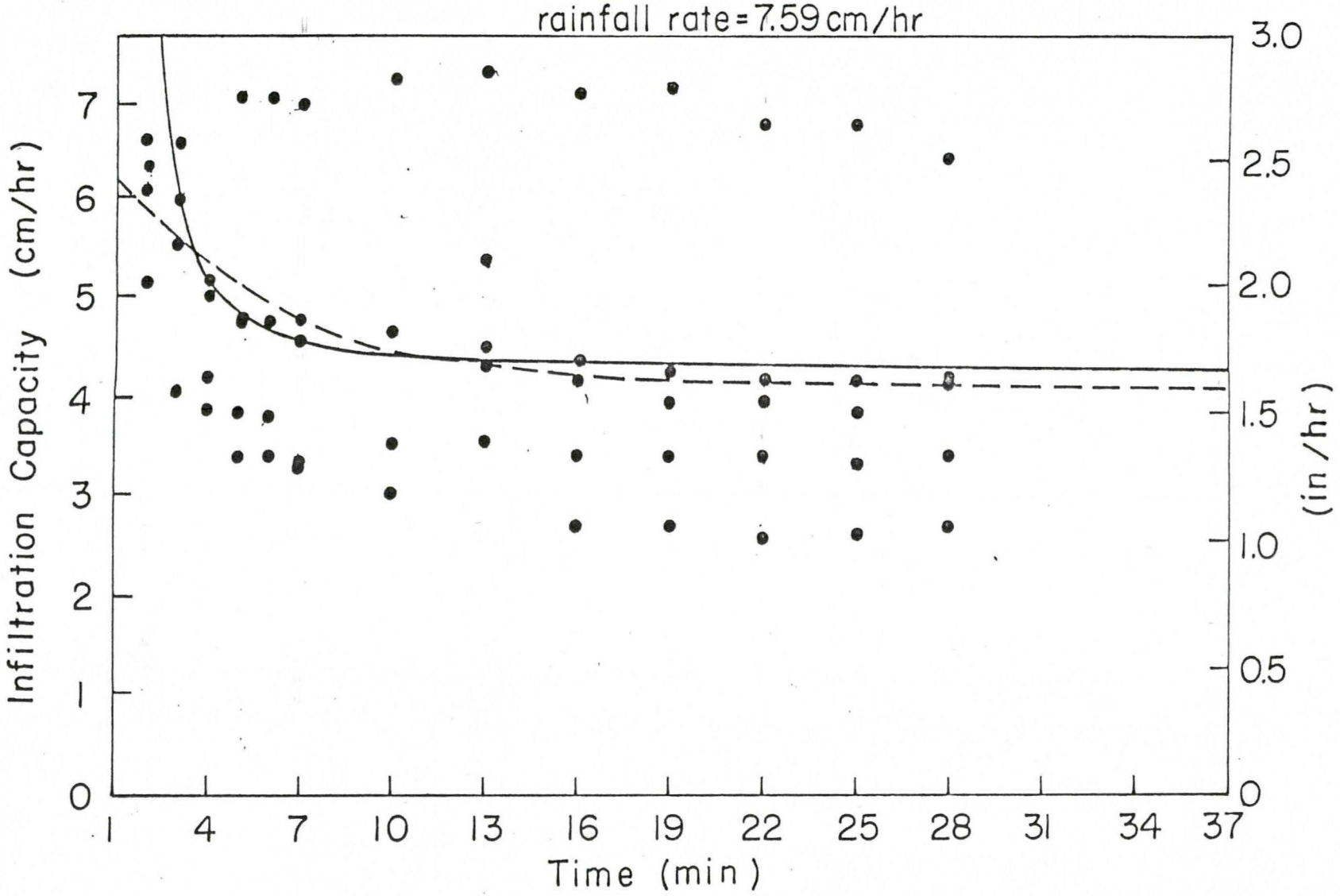


Figure 57. Infiltration curve for the tailings pond at Pacific Mine.

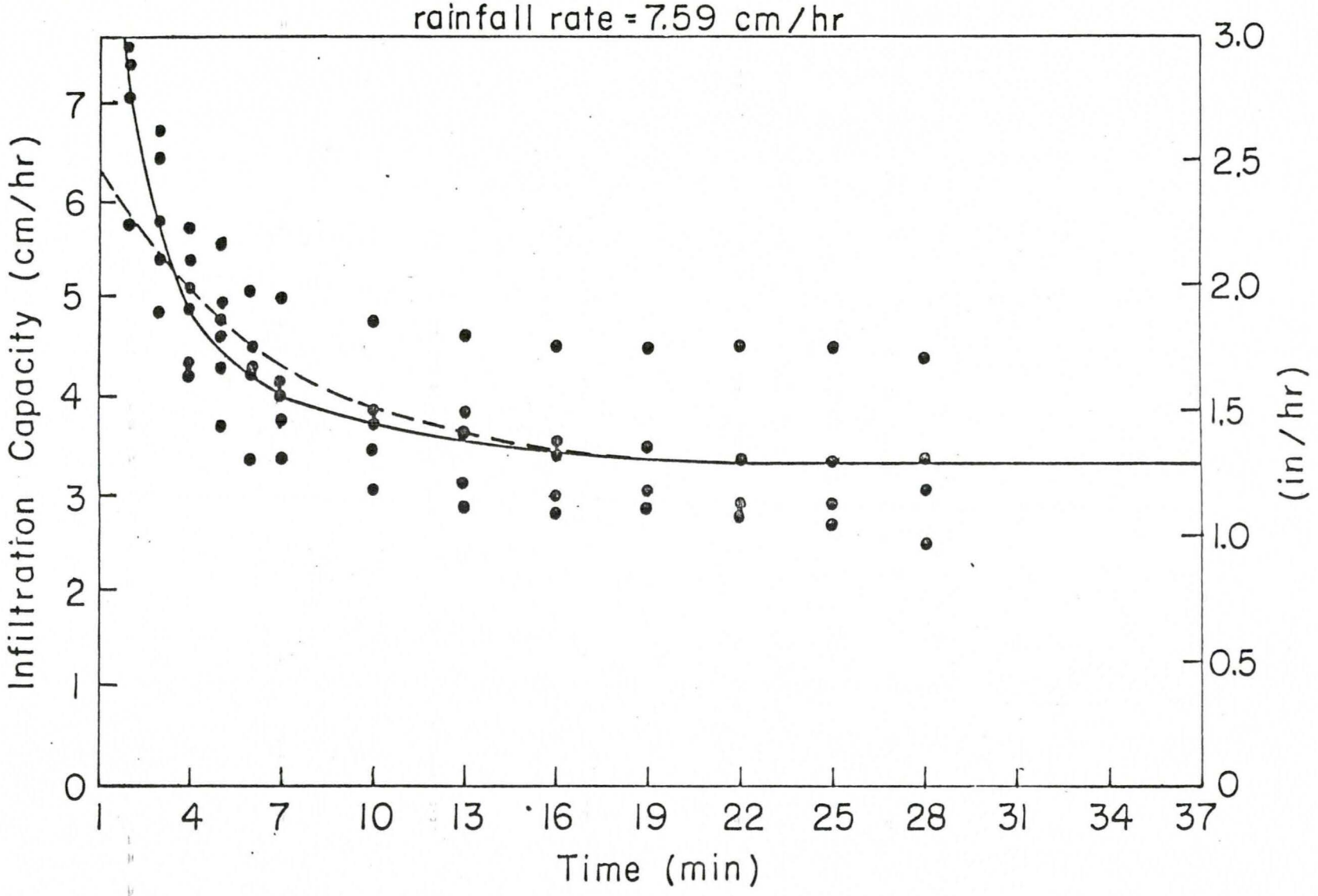


Figure 58. Infiltration curve for spoils at Pacific Mine.

From these observations, we might conclude that even though mining spoils and tailings might be derived from the same rock materials and at first inspection appear to be the same, past treatment and depositional histories may have a profound effect on their resultant surface-hydrologic characteristics.

P. Stubbs Clay

Stubbs Clay mine is located one steep mile east of the Edgemont L.D.S. Chapel on 40th North Street in Provo, Utah. The open-pit operation mined clay shales from either the Long Trail Shale Member of the Great Blue Limestone Formation or from the Mancos Shale Formation during the 1950s. Which formation the clays are derived from is uncertain (Hyatt, 1956). The McFarland, Smith, and Wadley deposits east of Pleasant Grove, Utah, are in the Long Trail Shale Member. The clay mines at Five Mile Pass, described in part A of this section, are in Mancos Shale.

Two samples were obtained at this site, one on slopes and the other on flats. Both the slopes and the flats have been compacted as a result of the heavy use of recreational vehicles that are attracted to the now-abandoned excavation.

Site characteristics are listed in table 21.

Q. Mill Creek

The clay mine in Mill Creek canyon near Kimberly, Utah, uses an open pit operation to mine brick clay which is sold to Interstate Brick Company.

Spoils are derived from reddish brown tuffaceous rhyolite, probably the Mount Belknap Rhyolite of Tertiary age (Callaghan and Parker, 1962). The spoils have a sandy loam texture, are quite loosely compacted, and are therefore characterized by a reasonably high infiltration capacity.

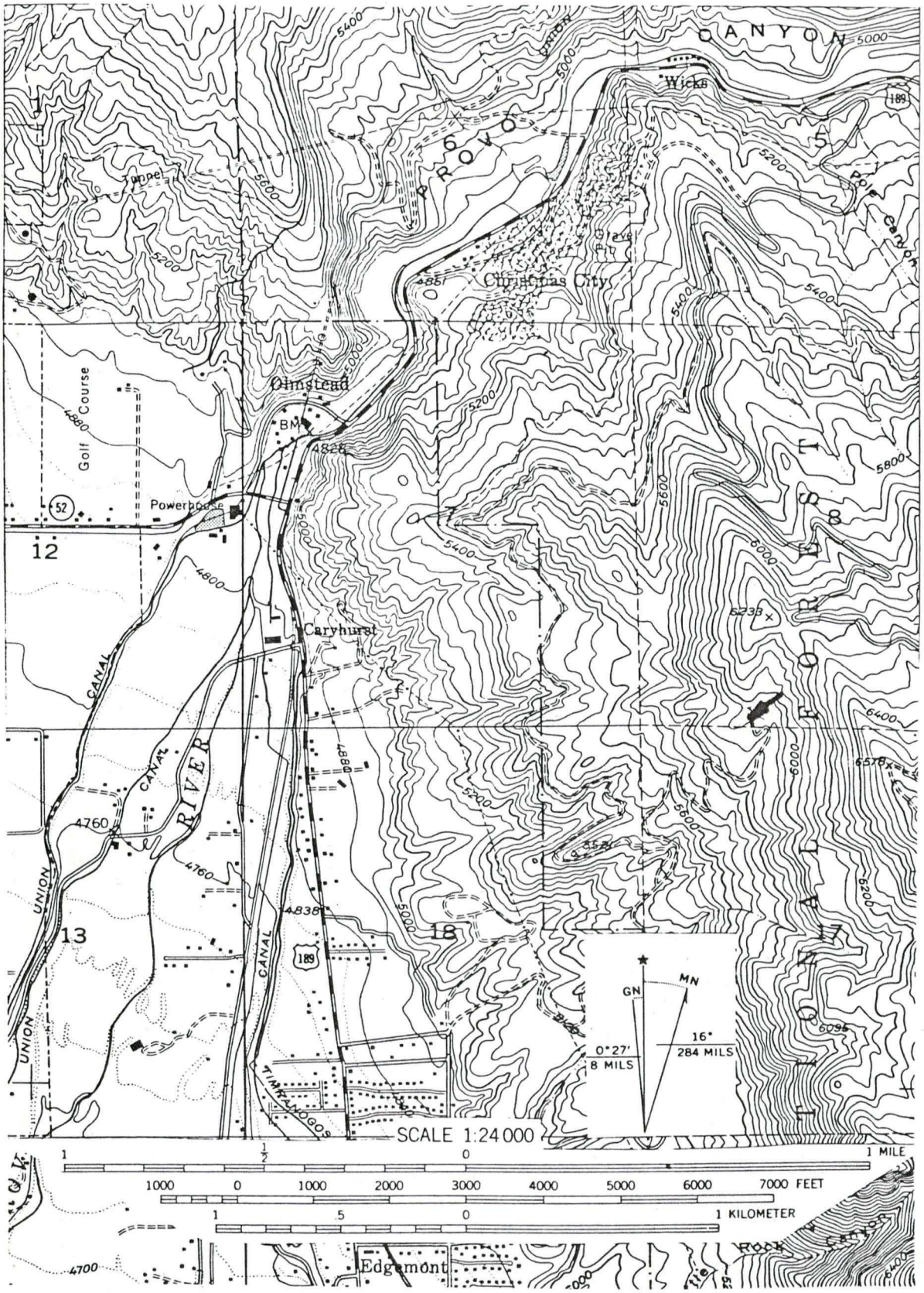


Figure 59. Map of Stubbs Clay Mine near Provo, Utah. Reprint, U.S.G.S. topographic, 7.5 minute quadrangle.

Figure 60. Stubbs Clay Mine: top, sampling area with Provo, Utah in background; bottom, closeup of spoils showing compaction by recreational vehicles and Utah Lake in background.

Table 21. Selected characteristics of site P, Stubbs Clay.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
Provo, Utah	5,860	Provo	1.5

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Great Blue limestone Mancos shale?	clay shale	13.33

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
66.1	33.1	Oak

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
S.W. (slope) S.W. (flat)	55 (slope) 13 (flat)	20 ft (slope) 250 ft (flat)	7.2	.9

[a] Hyatt, 1956. Clays of Utah County, Utah; and field inspection.

[b] U.S. Dept. of Commerce, Weather Bureau, 1952. Data for Provo, Utah.

[c] U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 21. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
5.8	.4	.1	< .1

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
43	silty clay	1.78 (slope) 1.98 (flat)

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
42	5009 (slope) 5528 (flat)	6.68 (slope) 7.24 (flat)

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
1.96 (slope) 2.57 (flat)	7,128 (slope) 6,609 (flat)	197.5 (slope) 41.5 (flat)

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 21. Continued

Chemical quality of runoff[f]					
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)				
	water applied	runoff			
27.7 (slope)	1.8 (slope)	1.8 (slope)			
6.3 (flat)	1.8 (flat)	2.6 (flat)			

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.8 (slope)	7.8 (slope)	< 100 (slope)	< 100 (slope)
7.8 (flat)	7.9 (flat)	< 100 (slope)	< 100 (flat)

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

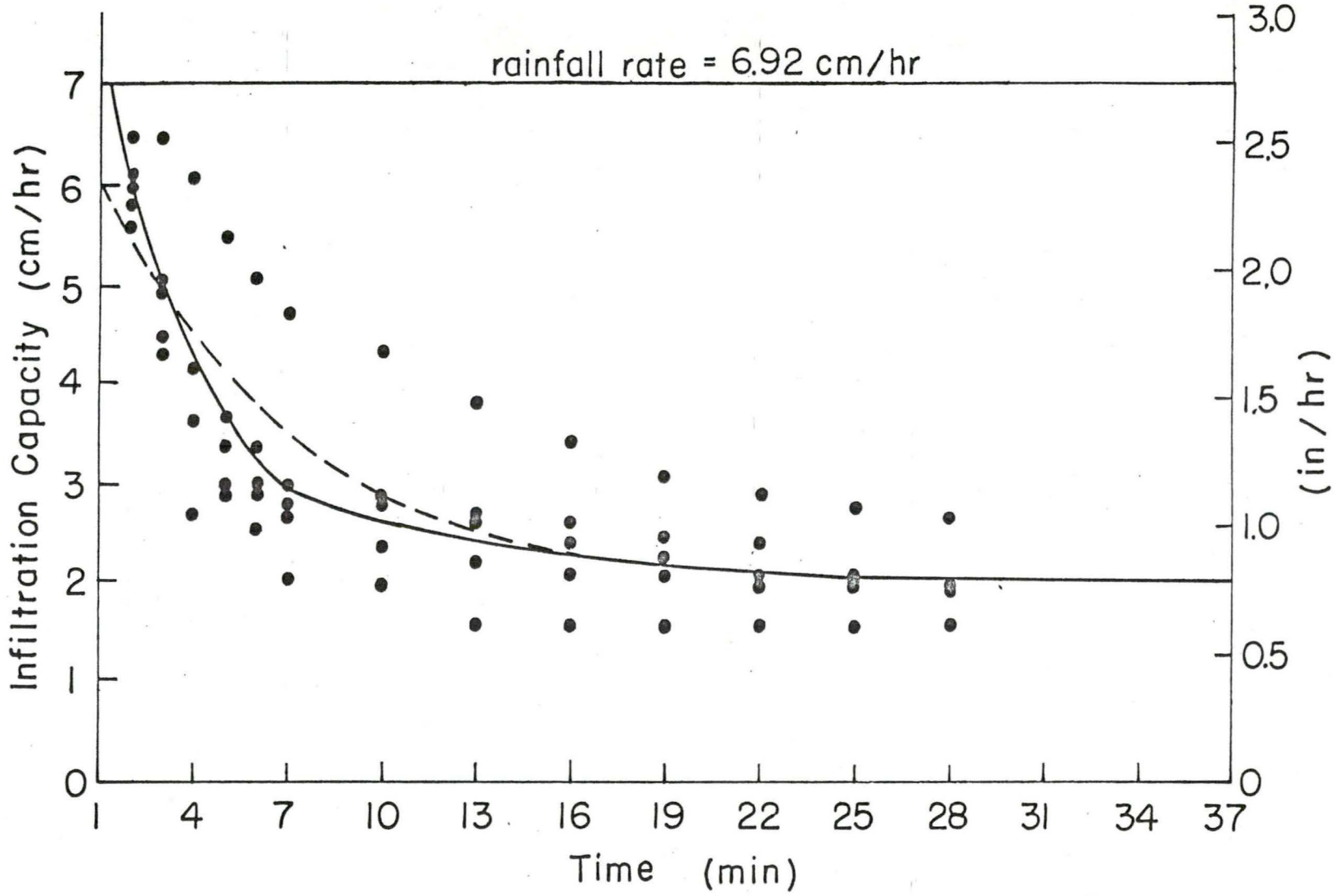


Figure 61. Infiltration curve for the spoils at Stubbs Clay Mine.

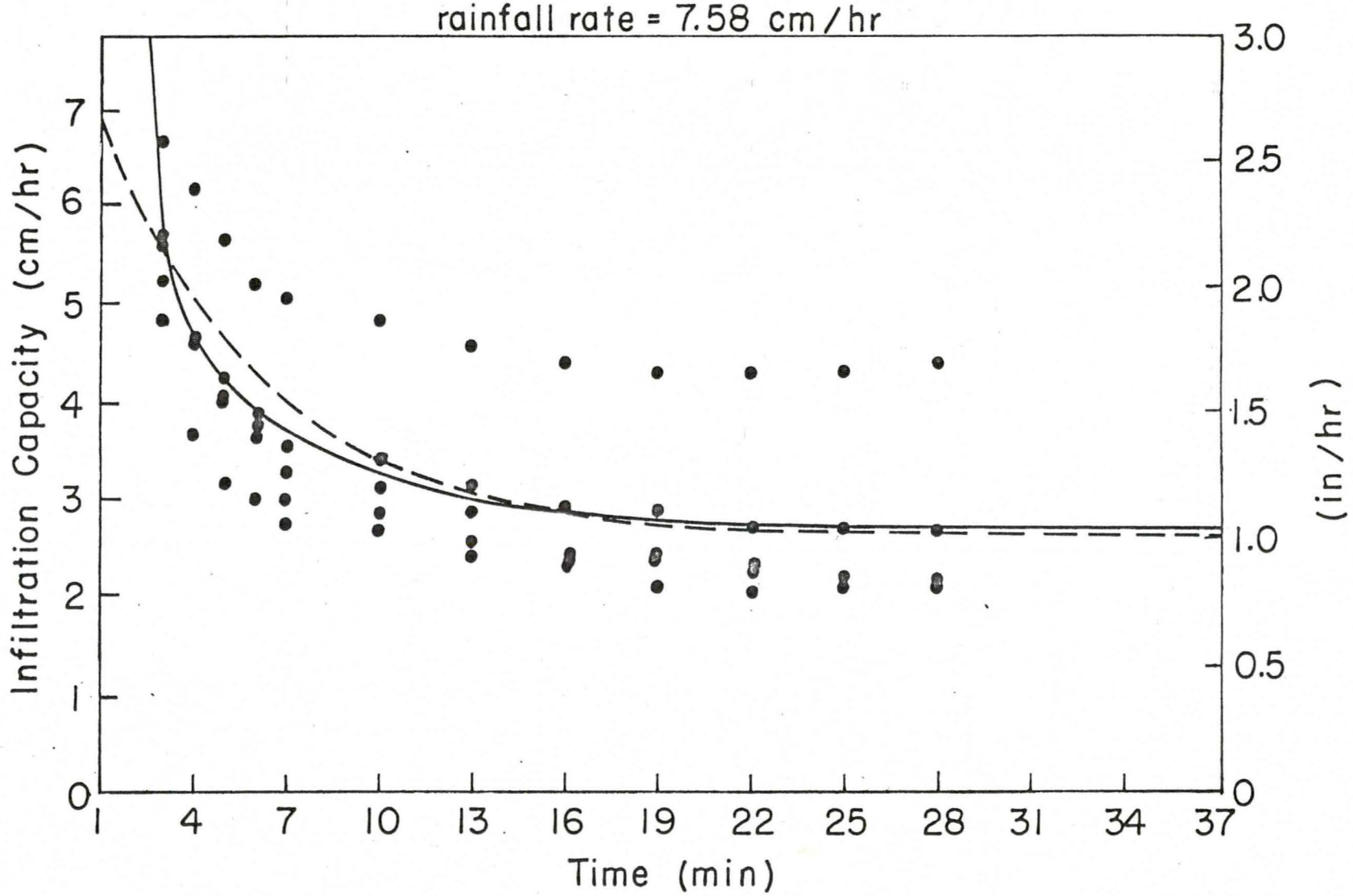


Figure 62. Infiltration curve for the spoils at Stubbs Clay Mine, (flat).

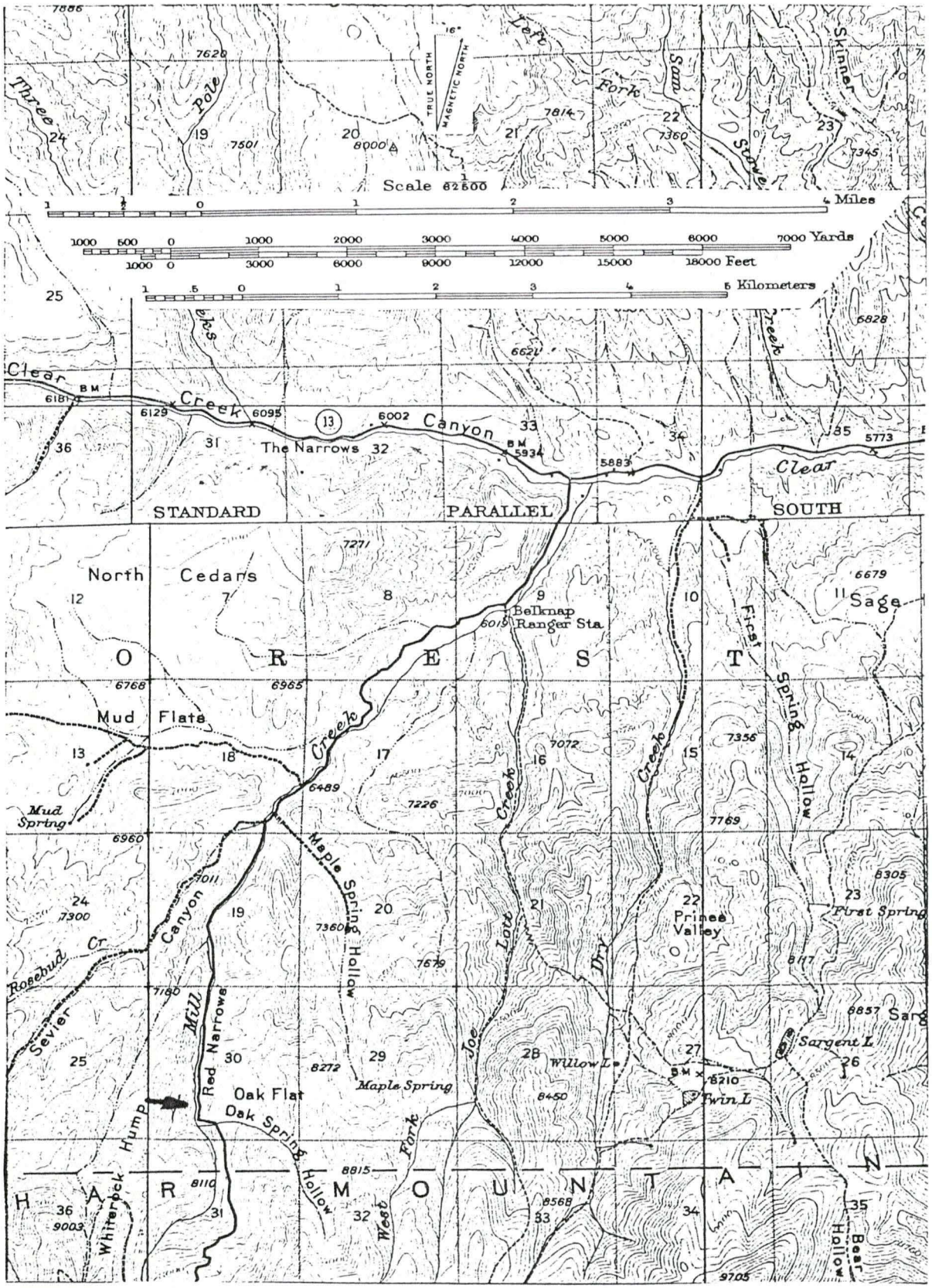


Figure 63. Map of the Mill Creek area. Utah. Reprint, U.S.G.S. topographic, 15 minute quadrangle.

Figure 64. Mill Creek Clay Mine: left, closeup of spoils materials; right, spoils slopes with stream at base.

Table22.Selected characteristics of site Q, Mill Creek.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
7 miles west of Sevier, Utah	7,300	Gold Mountain	2

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Tertiary Volcanics	Rhyolite and rhyolite tuffs	25.88

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
52.6	31.2	Pinyon Juniper

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
E	80	100 ft.	7.2	.6

[a]Callaghan and Parker, 1962. Geology of the Delano Peak Quadrangle, Utah; and field inspection.

[b]U.S. Dept. of Commerce, Weather Bureau, 1952. Data for Kimberly, Utah.

[c]U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 22. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
.9	.2	.1	< .1

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
63	Sandy loam	1.09

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
53	10,558	7.65

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
4.60	1,579	26.6

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 22. Continued

Chemical quality of runoff[f]		
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)	
	water applied	runoff
16.8	2.9	3.6

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.8	7.9	< 100	< 100

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

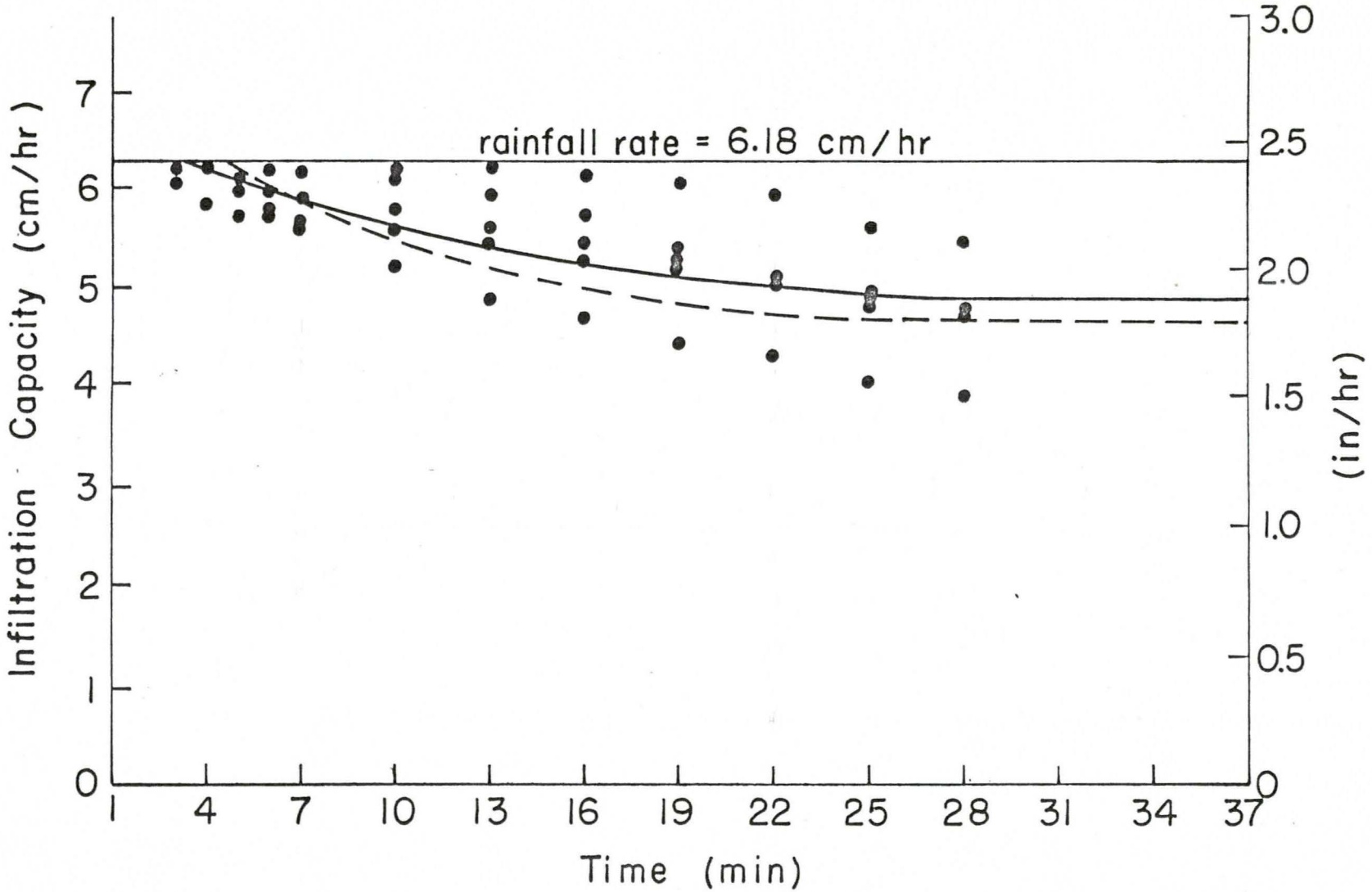


Figure 65. Infiltration curve for the spoils at Mill Creek Clay Mine.

A stream is located at the base of the slopes sampled (figure 64). Other site characteristics are listed on table 22.

R. Kimberly

The Annie Laurie Mine at the now abandoned town of Kimberly, Utah, was discovered in 1890 but didn't produce significantly until the advent of the cyanide process in 1899. After this time ores were treated successfully at a lower cost (Lindgen, 1906). Two large cyanide tailings ponds containing gray sandy deposits were sampled. The gray materials in these ponds were derived from chloritized, greenish-gray dacite rocks (volcanics) that were dry crushed and treated by the cyanide process. These rocks were mined for silver and are characterized by abnormally low sulfide contents.

Characteristics of surface hydrology for each pond are listed in table 23. Other characteristics listed in the table represent composites for both ponds. These tailings ponds are characterized by a complex of stratified lenses in the surface, which is typical of other ponds discussed in this report. Consequently the spread of points on the infiltration curves in figures 68 and 69 covers a wide range. This illustrates the large differences in infiltration capacity that are observed from one sample to the next.

One characteristic of the Kimberly ponds that seems to contribute to the variability in the infiltration capacities is the effect of wind-caused removal and deposition of fine sand grains on the pond surface. Infiltration rates were high in areas of deposition and low in areas of exposure. The exposed areas are typified by hard crusts that show evidence of rain-wash erosion. During intense rainstorms, runoff waters from these

Figure 66. Map of Kimberly and the Mount Belknap area, Utah. Reprint, U.S.G.S. topographic, 15 minute quadrangle.

Figure 67. Kimberly: top, tailings pond adjacent to stream; bottom, slope at edge of tailings pond nearest the stream showing lamination of water-layed materials and erosion.

Table 23. Selected characteristics of site R, Kimberly.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
12 miles west of Sevier, Utah	8,350	Gold Mountain	4

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Tertiary Volcanics	Dacite	25,88

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
52.6	31.2	Aspen Fir

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
N.W.	16	200 ft.	8.2	.4

[a] Lindgen, 1906. The Annie Laurie Mine, Piute County, Utah; and field inspection.

[b] U.S. Dept. of Commerce, Weather Bureau (1952). Data for Kimberly, Utah.

[c] U.S.U. Soil, Plant and Water Analysis Laboratory.

Table23. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
2.2	.2	< .1	< .1

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
33	sandy loam	1.60

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
49	10,021 (pond 1) 9,833 (pond 2)	9.12 (pond 1) 8.18 (pond 2)

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
5.59 (pond 1) 5.38 (pond 2)	2,115 (pond 1) 2,304 (pond 2)	7.8 (pond 1) 10.6 (pond 2)

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 23. Continued

Chemical quality of runoff[f]	
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)
	water applied / runoff
3.7 (pond 1)	2.9 (pond 1) / 2.9 (pond 1)
4.6 (pond 2)	2.9 (pond 2) / 3.2 (pond 2)

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.9 (pond 1)	8.0 (pond 1)	< 100 (pond 1)	<100 (pond 1)
7.9 (pond 2)	8.0 (pond 2)	< 100 (pond 2)	<100 (pond 2)

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

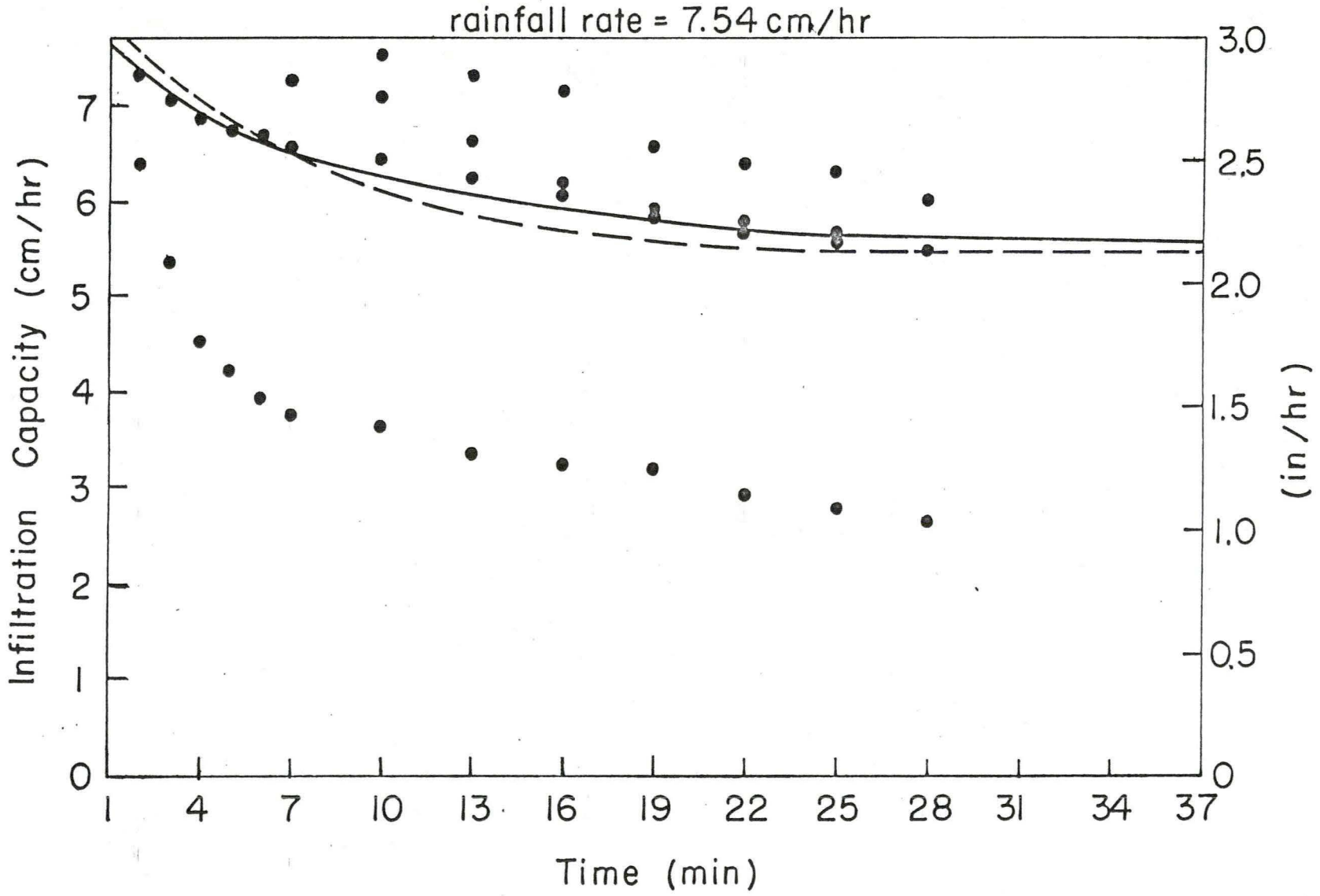


Figure 68. Infiltration curve for tailings pond A, Kimberly.

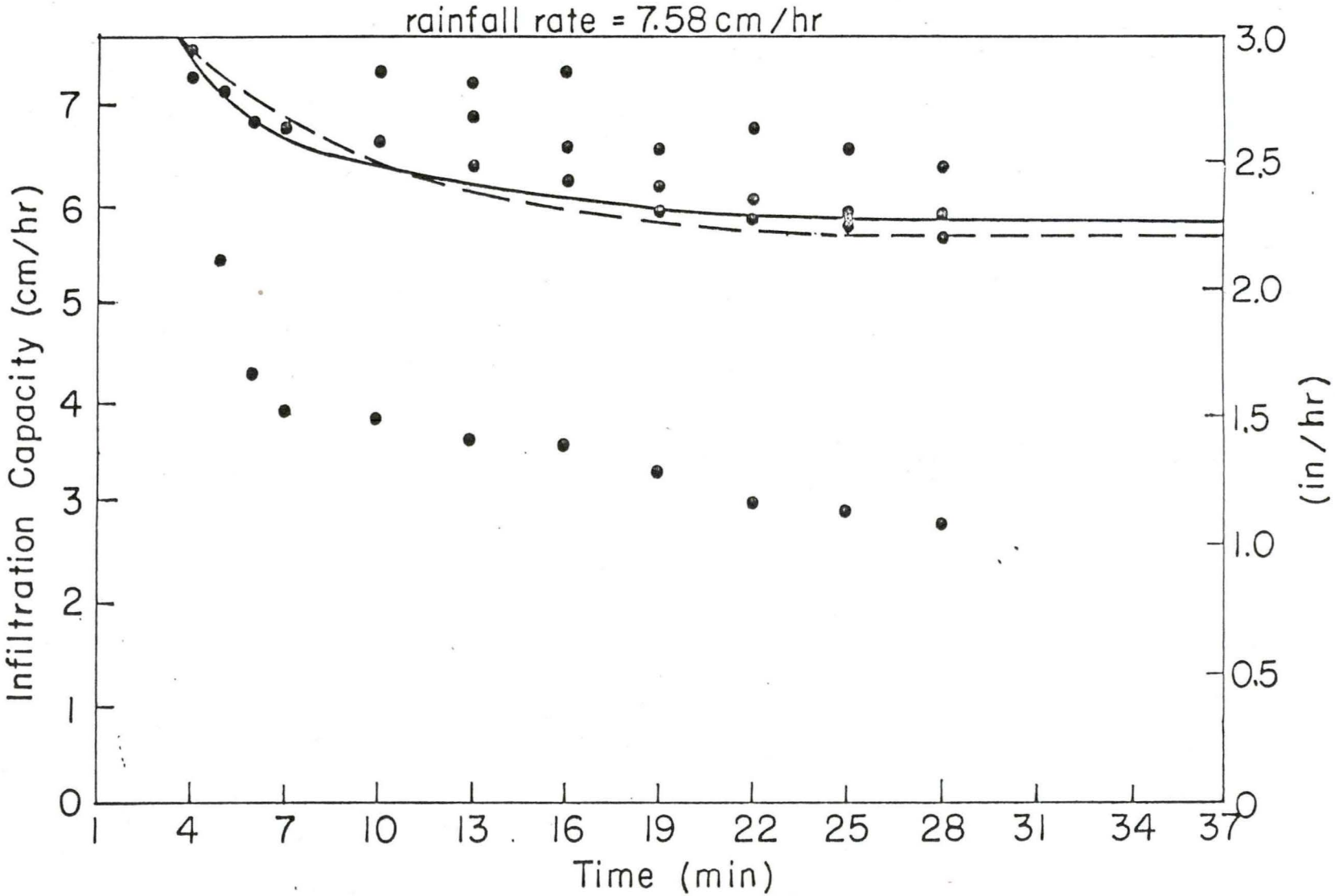


Figure 69. Infiltration curve for tailings pond B, Kimberly.

areas collect and discharge off the side of the tailings dump where they empty into a perennial stream (figure 67).

S. Box Creek

The Interstate Brick Company's lease located approximately 10 miles southwest of Koosharem, Utah, is an open-pit brick-clay mine. Clay is probably mined from latite tuffs and breccias containing stippled kaolinized rocks (Willard and Callaghan, 1962).

The spoils derived from this mine make an interesting comparison with those at the Mill Creek Clay Mine since they are derived from similar rock types and mining and disposal methods. Characteristics for surface hydrology at Box Creek are listed in table 24. Comparing tables 22 and 24 we see that spoils at both mines are very permeable and loose with high infiltration rates and bulk densities averaging only 1.07 and 1.09 respectively. Characteristics of surface materials listed in table 24 are for spoils only. Other characteristics describe an additional sample taken on the stock pile at this mine.

T. Hiawatha

A large tailings pond at Hiawatha, Utah, contains ash from burned coal that was mined some years ago in this area. Coal mining operations continue at the present time in this area, but the tailings pond has been abandoned.

Ash is light and easily lifted by wind currents. When strong winds are present, the area down wind of this deposit is said to appear as though it is covered by a large black cloud when viewed from a distance. Wind-blown deposits of ash are characteristically concentrated in areas on the pond.

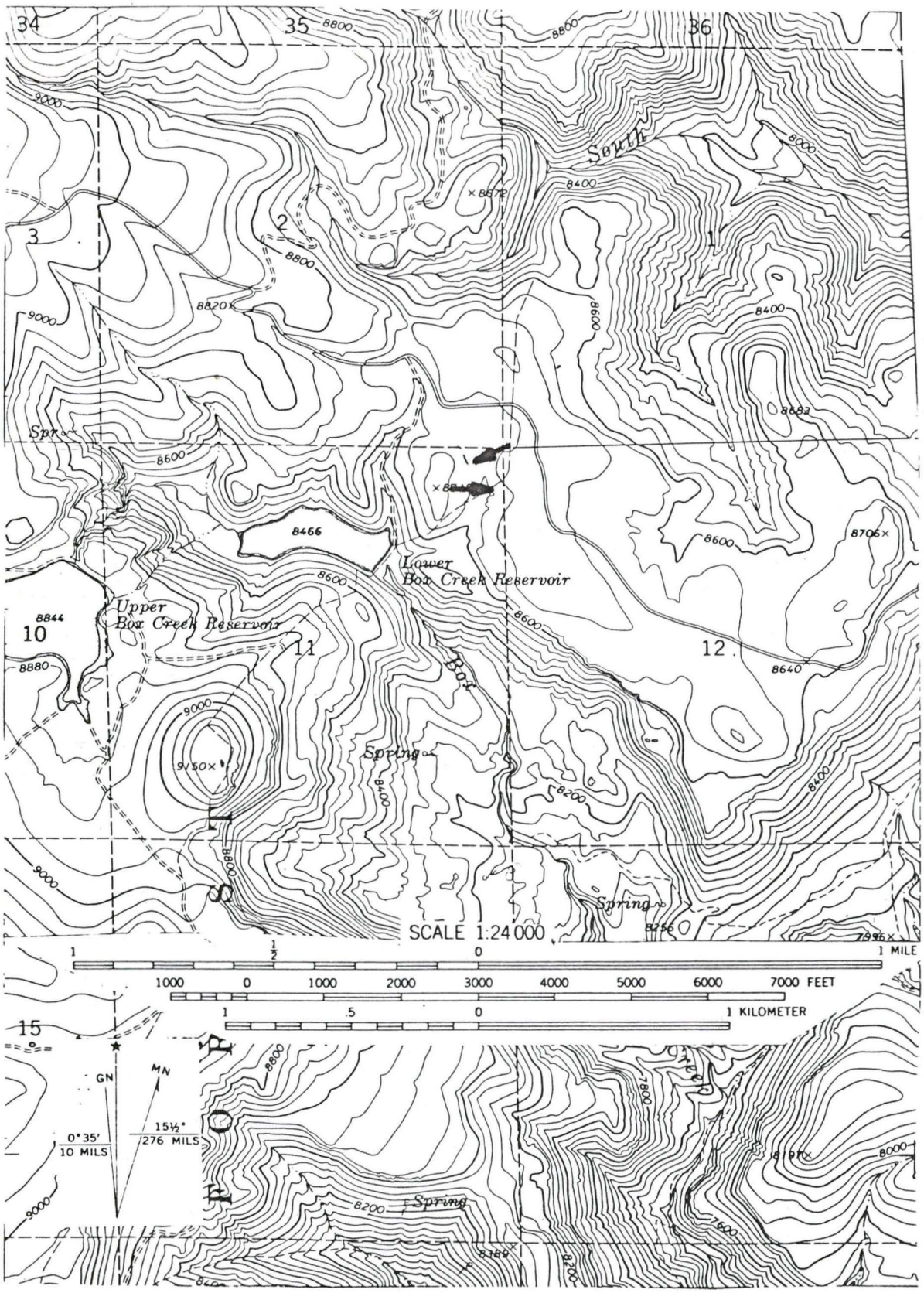


Figure 70. Map of the Box Creek area, Utah. Reprint, U.S.G.S. topographic, 7.5 minute quadrangle.

Figure 71. Box Creek Clay Mine: top, graded spoils; bottom. mining spoils above Lower Box Creek Reservoir.

Table24.Selected characteristics of site S. Box Creek.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
10 miles S.W. of Koosharem, Utah	8,700	Unnamed	20

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Bullion Canyon Volcanics	Latite tuffs and breccias	8.66

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
61.4	27.0	Fir Aspen Sage

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
E (spoils) W (stock-pile)	63 (spoils) 14 (stock-pile)	50 ft(spoils) 250 ft(stockpile)	7.6	1.1

[a]Willard and Callaghan, 1962. Geology of the Marysvale Quadrangle, Utah; and field inspection.

[b]U.S. Dept. of Commerce, Weather Bureau (1960). Data for Koosharem, Utah.

[c]U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 24. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
8.2	.4	.1	< .1

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
43	Sandy clay loam	1.07

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
62	10,802 (spoils) 9,743 (stockpile)	10.03 (spoils) 10.24 (stockpile)

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
4.70 (spoils) 4.45 (stockpile)	1,335 (spoils) 2,394 (stockpile)	18.4 (spoils) 2.6 (stockpile)

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 24. Continued

Chemical quality of runoff[f]		
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)	
	water applied	runoff
13.7 (spoils)	5.1 (spoils)	5.9 (spoils)
1.1 (stockpile)	5.1 (stockpile)	5.7 (stockpile)

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
8.3 (spoils)	7.8 (spoils)	100 (spoils)	100 (spoils)
8.3 (stockpile)	8.0 (stockpile)	100 (stockpile)	100 (stockpile)

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

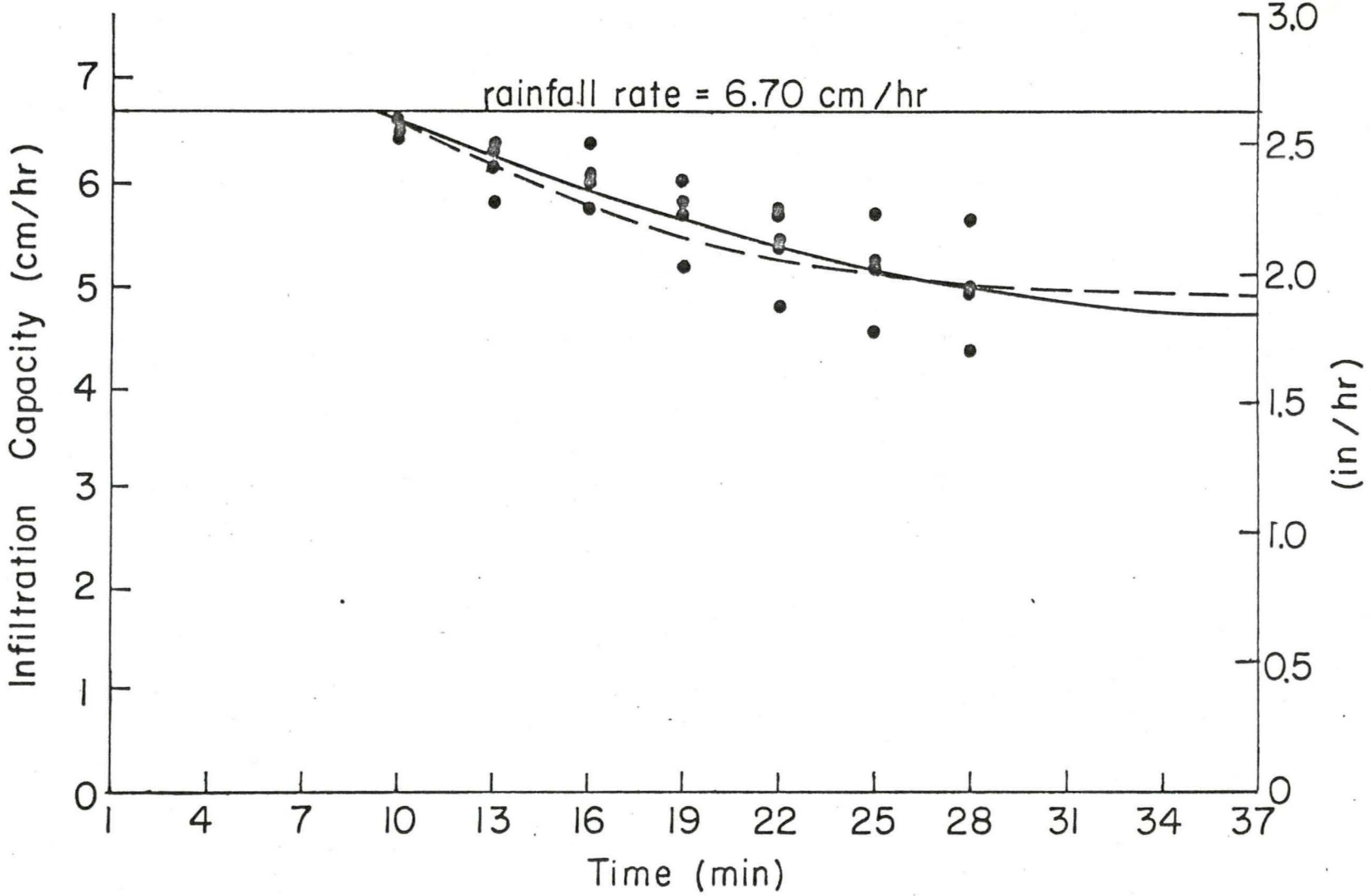


Figure 72. Infiltration curve for the spoils at Box Creek Clay Mine. (slopes)

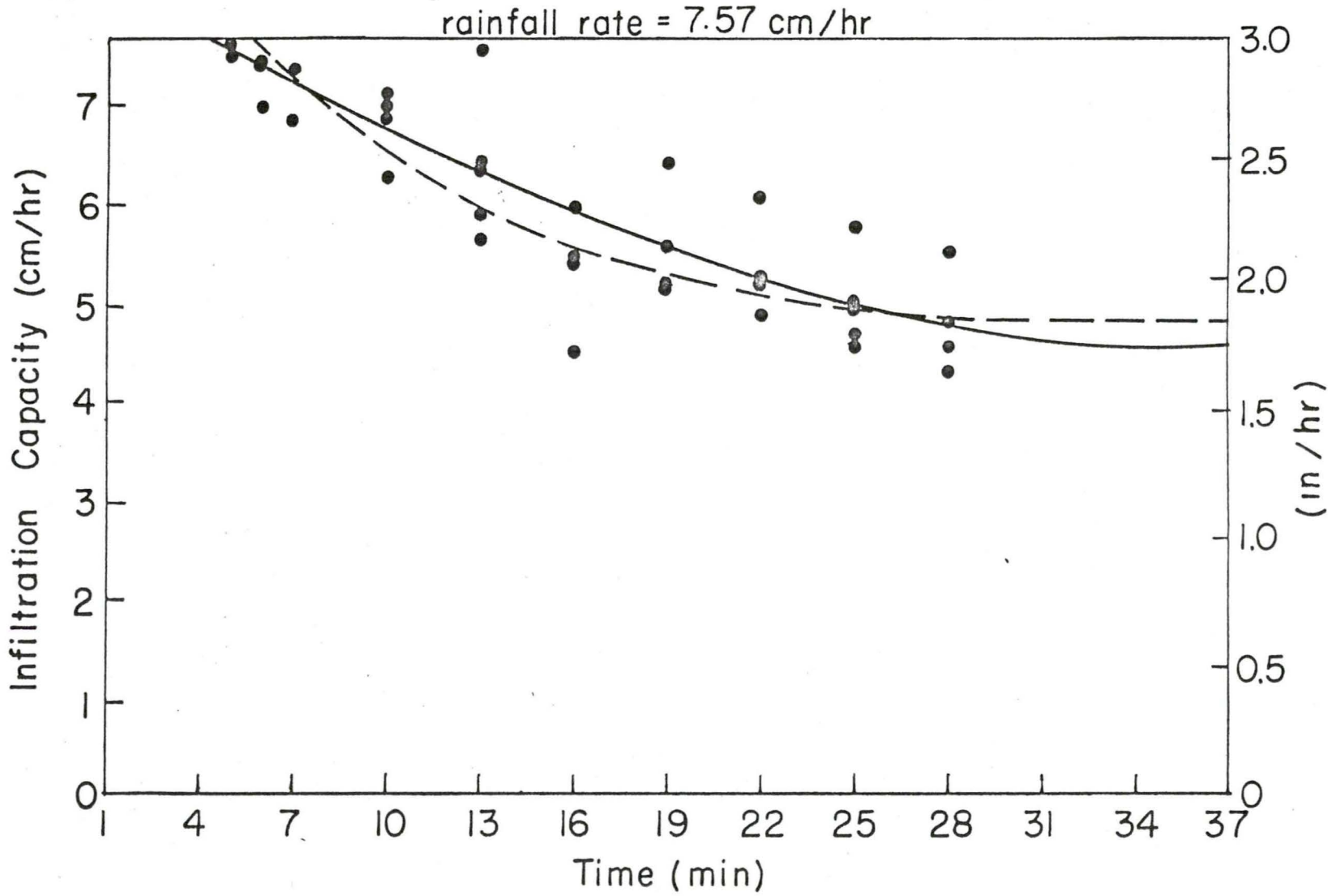


Figure 73. Infiltration curve for the stock pile at Box Creek Clay Mine.

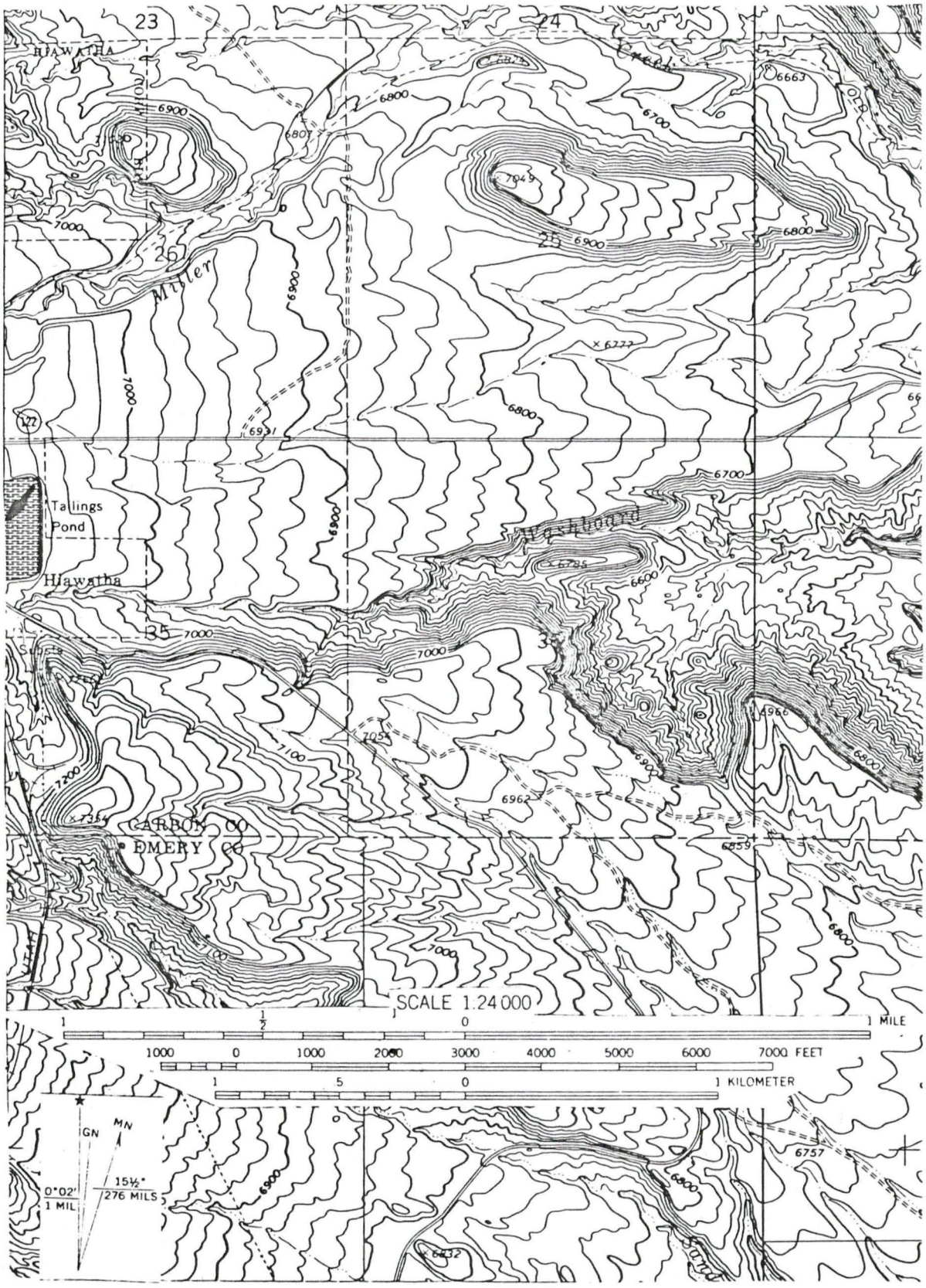


Figure 74. Map of the Hiawatha area, Utah. Reprint, U.S.G.S. topographic, 7.5 minute quadrangle.

Figure 75. Hiawatha Coal Mine: left, distant view of tailings pond; right, sampling area on the tailings pond.

Table25.Selected characteristics of site T, Hiawatha.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
Hiawatha, Utah	7,800	Carbon-Emery Coal	20

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Black Hawk formation	Shale Coal Ash	13.07

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
56.3	34.3	Pinyon Juniper

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
5	9	10 ft. to 500 ft.	6.5	3.3

[a]Clark, 1928. Geology of the Castle Gate, Wellington and Sunnyside Quadrangles, Carbon County, Utah; and field inspection.

[b]U.S. Dept. of Commerce, Weather Bureau, 1960. Data for Hiawatha, Utah.

[c]U.S.U. Soil, Plant and Water Analysis Laboratory.

Table 25. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
1.7	8.5	.1	5.8

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
72	sandy loam	0.74

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
37	5,073	5.56

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
2.18	7,064	106.9

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 25.Continued

Chemical quality of runoff[f]		
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)	
	water applied	runoff
15.1	3.2	3.9

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.8	7.7	100	100

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

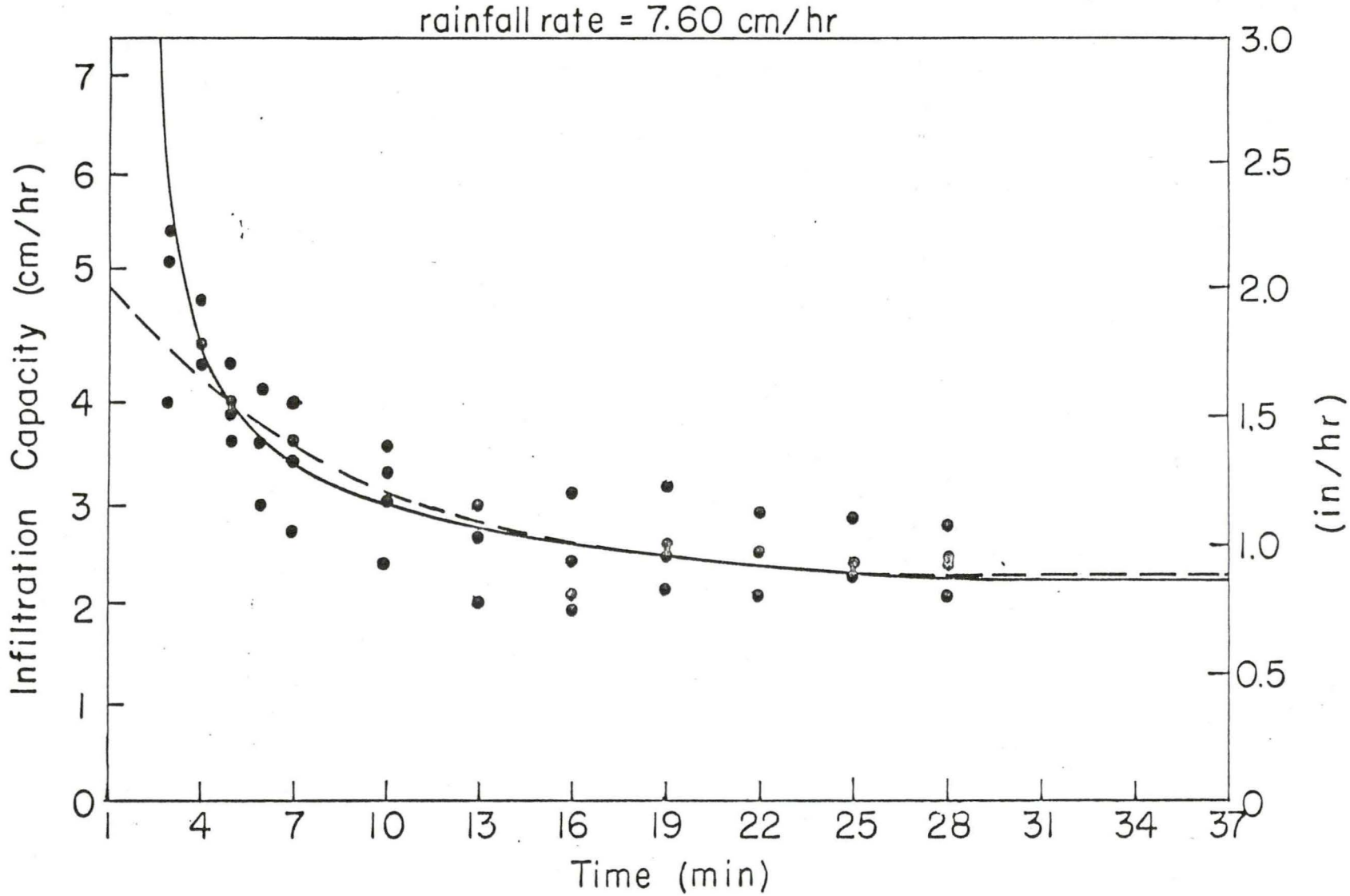


Figure 76. Infiltration curve for the tailings pond at Hiawatha.

Samples of surface hydrology obtained for this site do not compare with samples obtained for other tailings ponds. The presence of ash regulates the unique surface conditions of this deposit. The non-wettability characteristic of ash produces uniformly low infiltration capacities. This is shown in table 25. Note that texture is similar to other tailings ponds sampled in this project.

Light weight ash materials are carried away easily by runoff waters even on this deposit where average slopes are only 9%. Potential sediment production was also high on ash sampled at Castle Gate.

U. Old Frisco

The Horn Silver Mine at the ghost town of Old Frisco, Utah, was discovered in 1875. The properties came into the possession of the Horn Silver Mining Company in 1879 after which it became one of the largest producers of silver in the state (Butler, 1913).

In the early eays, the ores were smelted at Old Frisco located about one-half mile from the mine. In 1893 a stamp mill was constructed at the mine site. It was used until 1905 for concentrating low grade ores. The ores were crushed in the mill and tailings were deposited on its east side.

Spoils and tailings were derived from hydrothermally altered limestones and lavas which now contain some iron oxides, silica, and barite. The tailings are acid for reasons not entirely understood. It is believed that the silver bearing ore was associated with sulfides (as it commonly is) and that these metals, upon treatment, were crushed and then disseminated in the tailings.

The tailings are characterized by a hard surface crust about one-half inch think, and salts have precipitated on the surface in many areas.

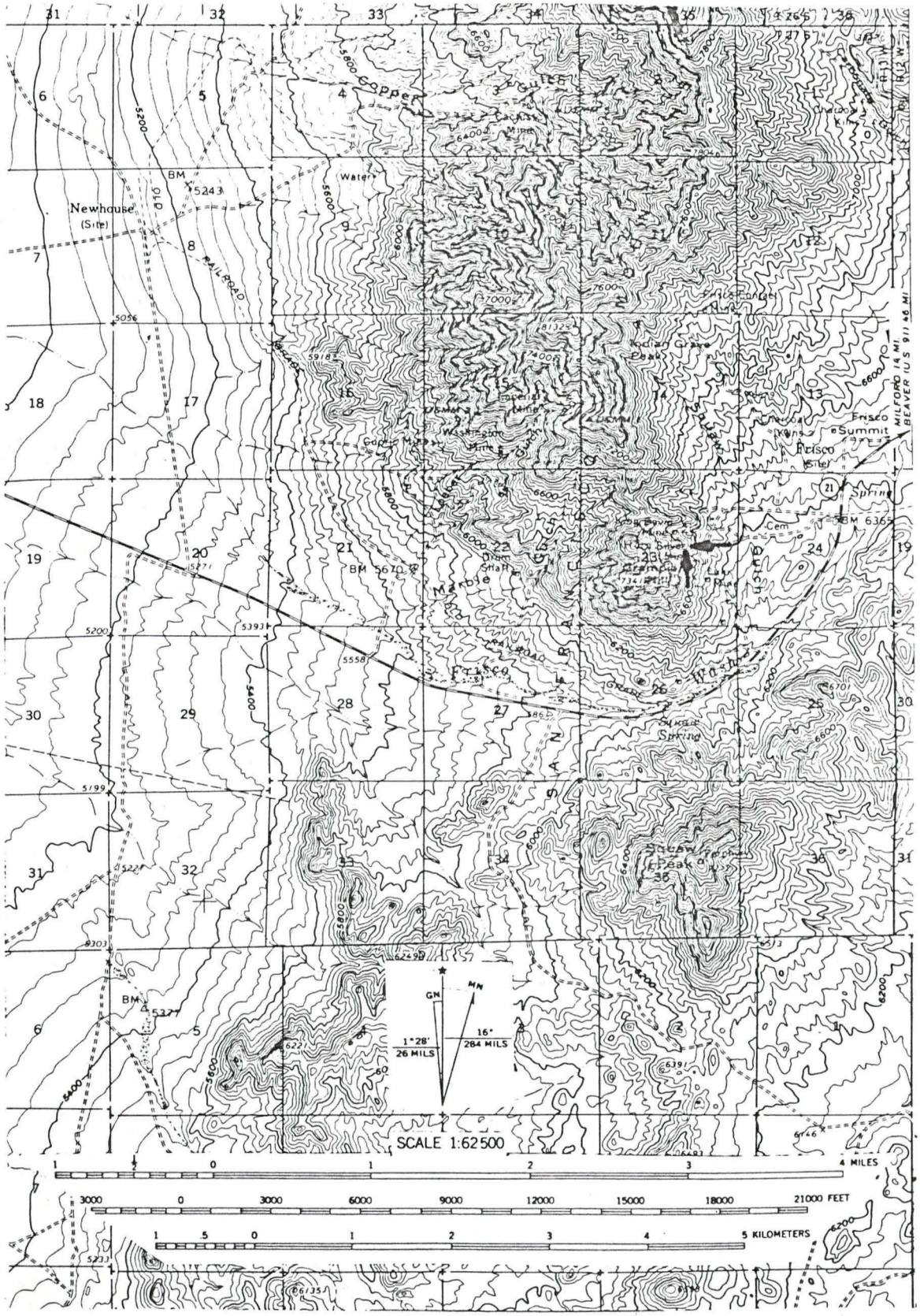


Figure 77. Map of the San Francisco area, Utah. Reprint, U.S.G.S. topographic, 15 minute quadrangle.

Figure 78. Old Frisco: top, overall view of Horn Silver Mine; bottom, spoils of the same mine.

Figure 78. (Continued) top, acid tailings from Horn Silver Mine; bottom, several types of waste products from the mills at Old Frisco.

Table26.Selected characteristics of site U1, Old Frisco, Tailings.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
15 miles west of Milford, Utah	6,600	San Francisco	10

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
San Francisco Quartz Monzonite Stock	Limestone altered limestone quartz monzonite intermediate volcanics	5.63

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
65.1	33.3	Artemisia

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
W	56	75 ft.	5.2	22.0

[a]Butler, 1913. Geology and ore deposits of the San Francisco and adjacent districts, Utah; and field inspection.

[b]U.S. Dept. of Commerce, Weather Bureau, 1960. Data for Wah Wah and Milford, Utah.

[c]U.S.U. Soil, Plant, and Water Analysis Laboratory.

Table 26. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
1.2	.87	.1	330.1

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
39	clay loam	1.49

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
43	5,320	7.24

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
2.03	6,817	67.4

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 26. Continued

Chemical quality of runoff[f]		
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)	
	water applied	runoff
9.9	3.3	30.0

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.6	4.0	800	2,100

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

Table27. Selected characteristics of site U2, Old Frisco, Spoils.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
15 miles west of Milford, Utah		San Francisco	5

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
San Francisco Quartz Monzonite Stock	Limestone altered limestone quartz monzonite intermediate volcanics	5.63

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
65.1	33.3	Artemisia

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
N	76	50 ft.	8.0	1.5

[a] Buther, 1913. Geology and ore deposits of the San Francisco and adjacent districts, Utah; and field inspection.

[b] U.S. Dept. of Commerce, Weather Bureau, 1960. Data for Wah Wah and Milford, Utah.

[c] U.S.U. Soil, Plant and Water Analysis Laboratory

Table 27. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
3.0	.32	.4	5.7

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
50	clay loam	1.56

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
39	6,122	6.45

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
2.21	6,015	28.4

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 27. Continued

Chemical quality of runoff[f]		
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)	
	water applied	runoff
4.7	2.1	3.4

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
8.0	7.5	< 100	2,800

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

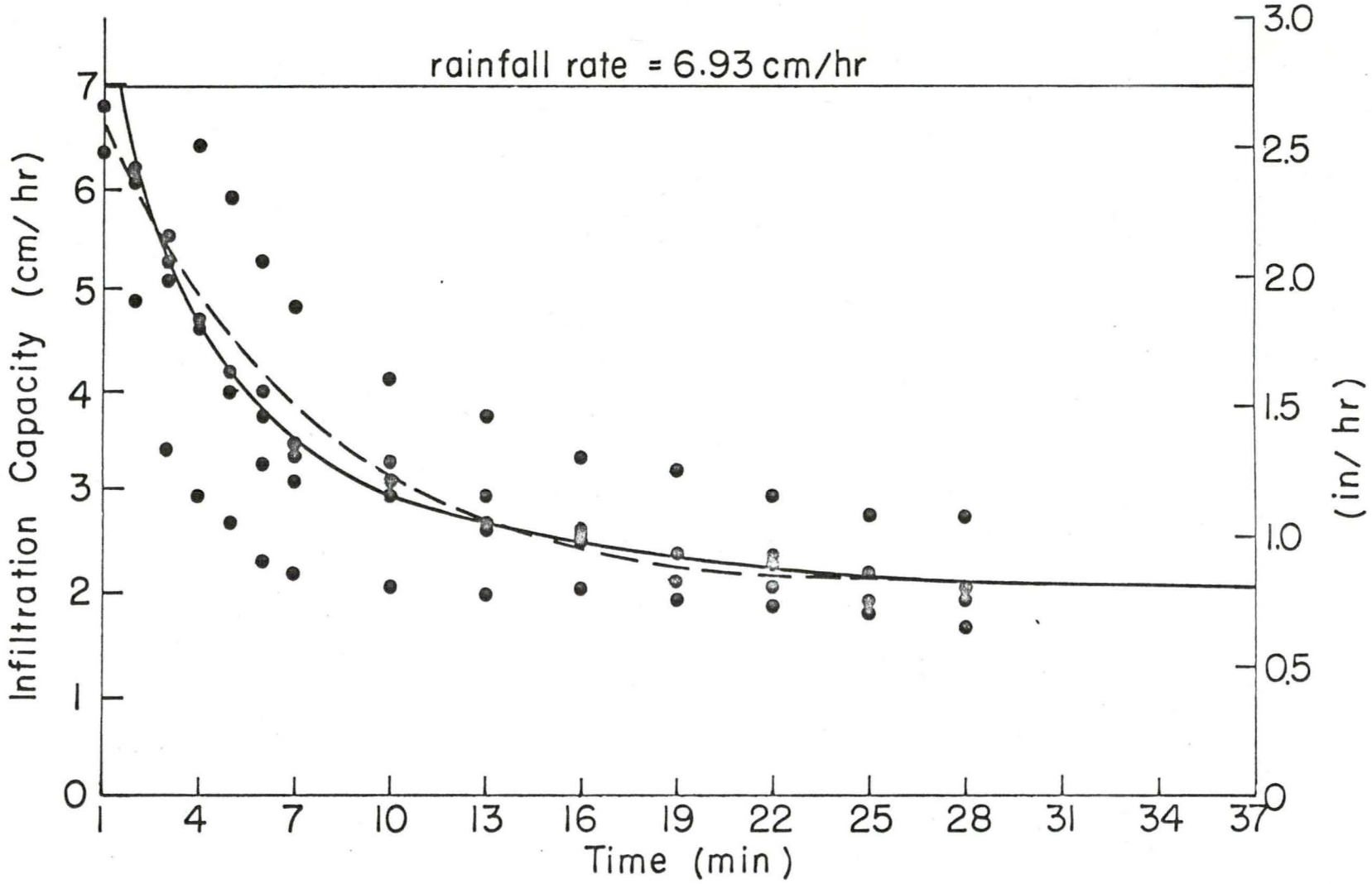


Figure 79. Infiltration curve for the tailings at Horn Silver Mine.

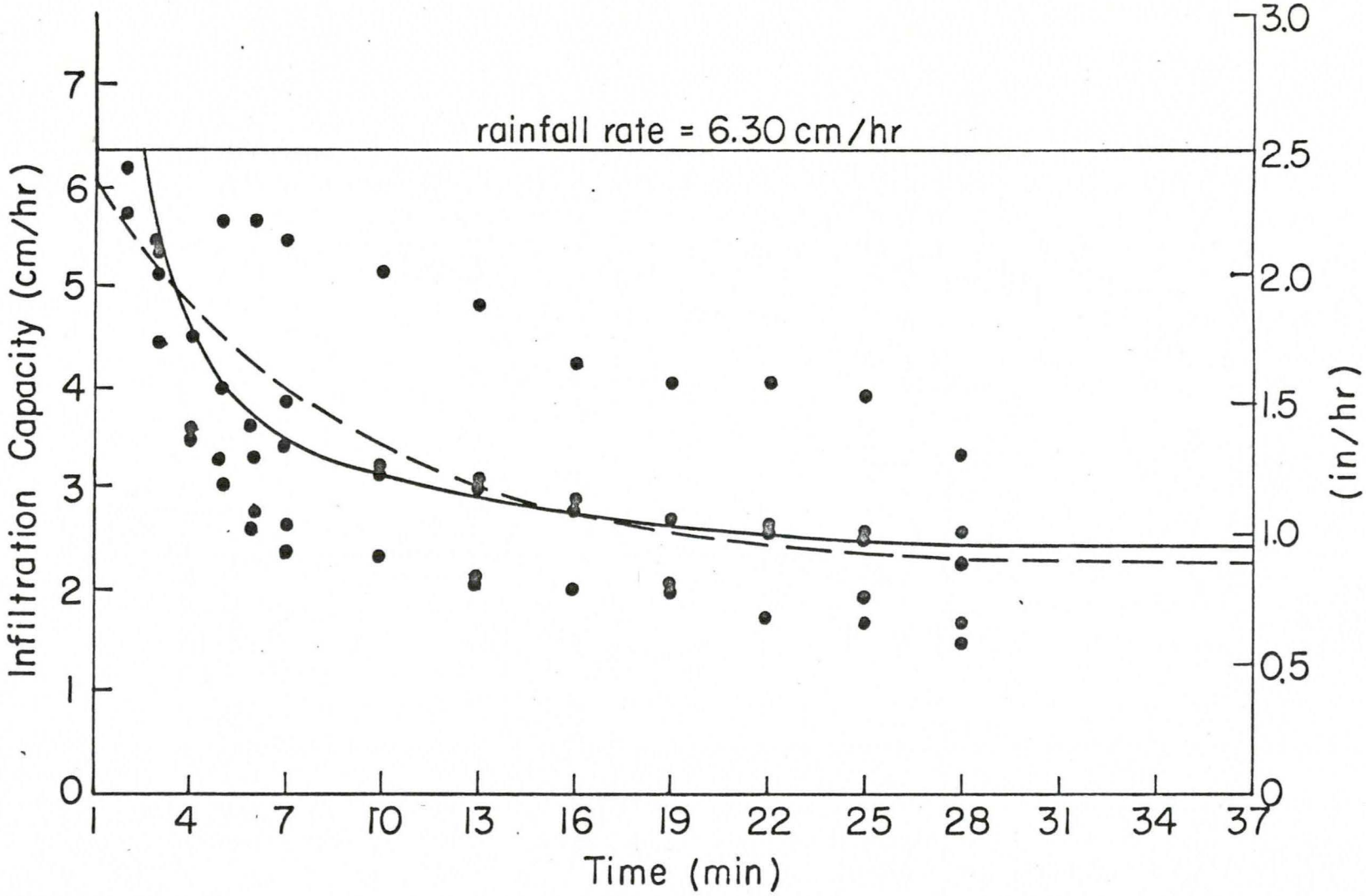


Figure 80. Infiltration curve for the spoils at Horn Silver Mine.

Infiltration capacity is lower as a result than on the spoils representing the same rocks. Upon comparison of the spoils and tailings characteristics shown in tables 26 and 27, we see that potential sediment production is much greater on tailings than on spoils even though slopes associated with the spoils are steeper. This erosional difference is thought to be a function of rock sizes on the plot surfaces. Erosion is reduced somewhat by the presence of pebbles and rocks on the spoils plot. The percentage of grains larger than 2 cm covering the surface area of a spoils plot was estimated to average 30 percent. Tailings were estimated at only 10 percent rock cover. Lack of large rocks in the tailings can be attributed to crushing processes in the mill.

V. Castle Gate

Castle Gate is located about 10 miles northwest of Price, Utah. It is the site of Utah Power and Light Company's power plant that uses coal as a source for energy. The coal is mined from the Black Hawk Formation of the Mesa Verde Group.

Several types of spoils can be found in this area including ash, which is derived from the burning of coal at the plant, and spoils consisting of coal-bearing shale mixed with ash. The ash spoils have been partly revegetated. A layer of soil about 6 inches deep was placed on the surface of these spoils and later seeded with crested wheat. The photographs in figure 82 show that revegetation has been successful.

Three samples of surface hydrology were taken in the area. Two were obtained for the ash comparing the bare spoils with the revegetated spoils. Characteristics of these sites are listed in table 28. The other sample was obtained from the spoils containing shale and low grade coal. Table 29 lists characteristics of the latter.

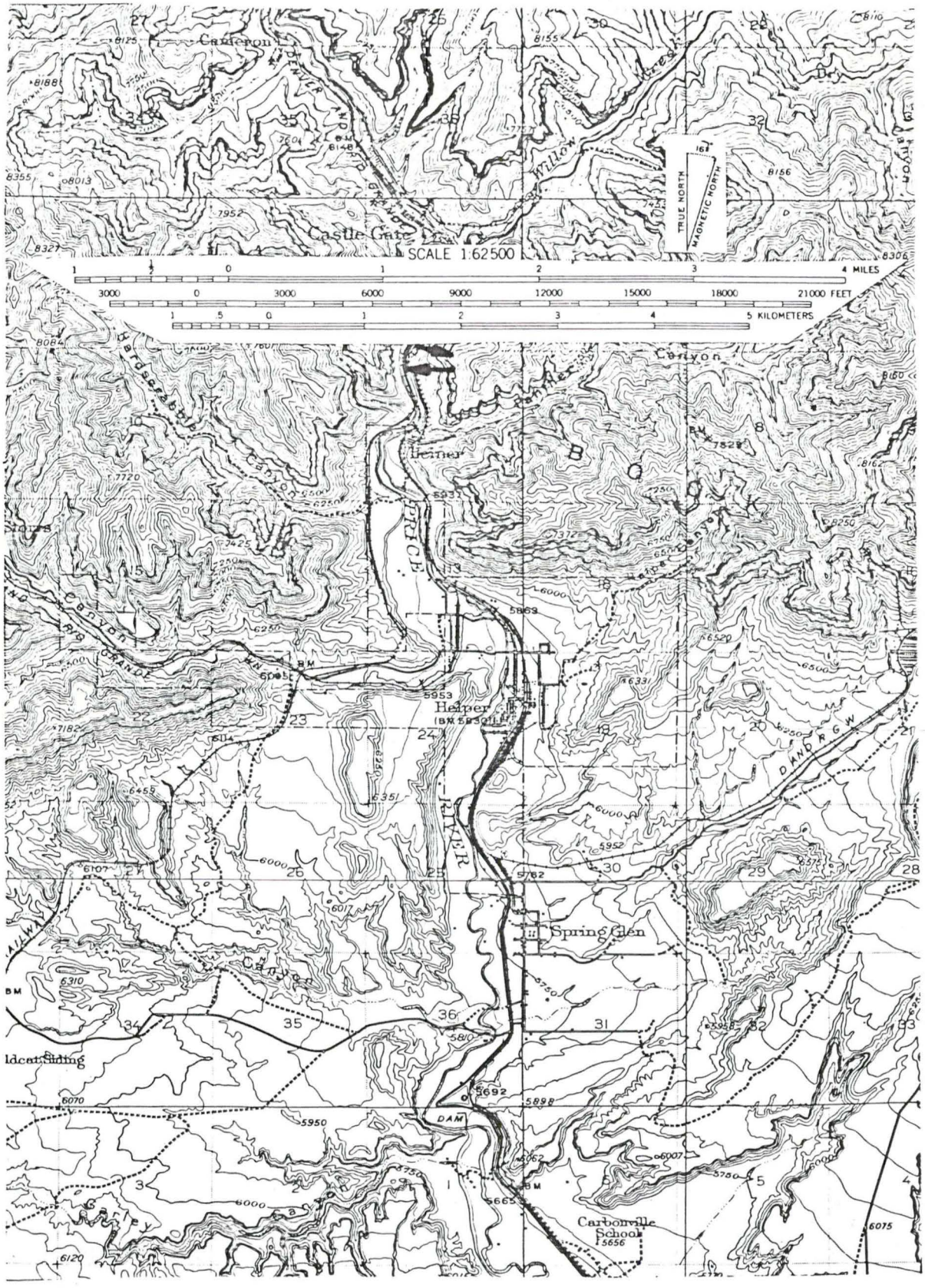


Figure 81. Map of the Castle Gate area in Price River Canyon, Utah. Reprint, U.S.G.S. topographic, 15 minute quadrangle.

Figure 82. Castle Gate Coal Mines: top, overall view of ash piles showing revegetated materials at left; bottom, close view of the revegetated spoils in the upper photo.

Figure 82. (Continued) top, Price River under-cutting ash at Castlegate; bottom, sampled spoils pile adjacent to stream.

Table28. Selected characteristics of site V1, Castle Gate, Ash.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
3 miles north of Helper, Utah	6,000	Carbon-Emery Coal	4

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Black Hawk Formation	Shale Coal	9.76

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
64.1	33.7	Pinyon Juniper

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
W (unseeded)	66(unseeded)	90 ft (unseeded)	7.7 (unseeded)	2.5 (unseeded)
W (seeded)	34 (seeded)	70 ft. (seeded)	7.7 (seeded)	2.2 (seeded

[a] Clark, 1928. Geology of the Castle Gate, Wellington and Sunnyside Quadrangles, Carbon County, Utah; and field inspection.

[b] U.S. Dept. of Commerce, Weather Bureau, 1960. Data for Price, Utah.

[c] U.S.U. Soil, Plant and Water Analysis Laboratory

Table 28 Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
11.0 (unseeded)	1.89 (unseeded)	.2 (unseeded)	26.7 (unseeded)
7.5 (seeded)	.47 (seeded)	< .1 (seeded)	29.3 (seeded)

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
37 (unseeded)	silt loam (unseeded)	1.21 (unseeded)
10 (seeded)	silt loam (seeded)	1.02 (seeded)

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
41 (unseeded)	7,166 (unseeded)	6.35 (unseeded)
30 (seeded)	*20,663 (seeded)	21.62 (seeded)

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
3.25 (unseeded)	4,971 (unseeded)	205.9 (unseeded)
11.18 (seeded)	* 420 (seeded)	3.0 (seeded)

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

*For a twenty-eight minute application of rain falling at a rate of 6 inches/hour.

Table 28. Continued

Chemical quality of runoff[f]			
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)		
	water applied	runoff	
41.4 (unseeded)	3.2 (unseeded)	3.9 (unseeded)	
7.1 (seeded)	4.3 (seeded)	5.3 (seeded)	

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.8 (unseeded)	8.1 (unseeded)	100 (unseeded)	400 (unseeded)
7.6 (seeded)	7.9 (seeded)	200 (seeded)	200 (seeded)

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

Table29.Selected characteristics of site V2, Castle Gate, Spoils.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
3 miles north of Helper, Utah	6,000	Carbon-Emery Coal	3

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Black Hawk Formation	Shale Coal	9.76

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
64.1	33.7	Pinyon juniper

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
E		100 ft.	7.2	3.0

[a]Clark, 1928. Geology of the Castle Gate, Wellington, and Sunnyside Quadrangles, Carbon County, Utah; and field inspection.

[b]U.S. Dept. of Commerce, Weather Bureau, 1960. Data for Price, Utah.

[c]U.S.U. Soil, Plant and Water Analysis Laboratory

Table 29. Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
7.7	18.8	< .1	33.4

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
45	sandy loam	0.89

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
46	7,771	6.05

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
3.73	4,366	27.6

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 29. Continued

Chemical quality of runoff[f]		
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)	
	water applied	runoff
6.3	4.2	6.2

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.6	8.1	200	200

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

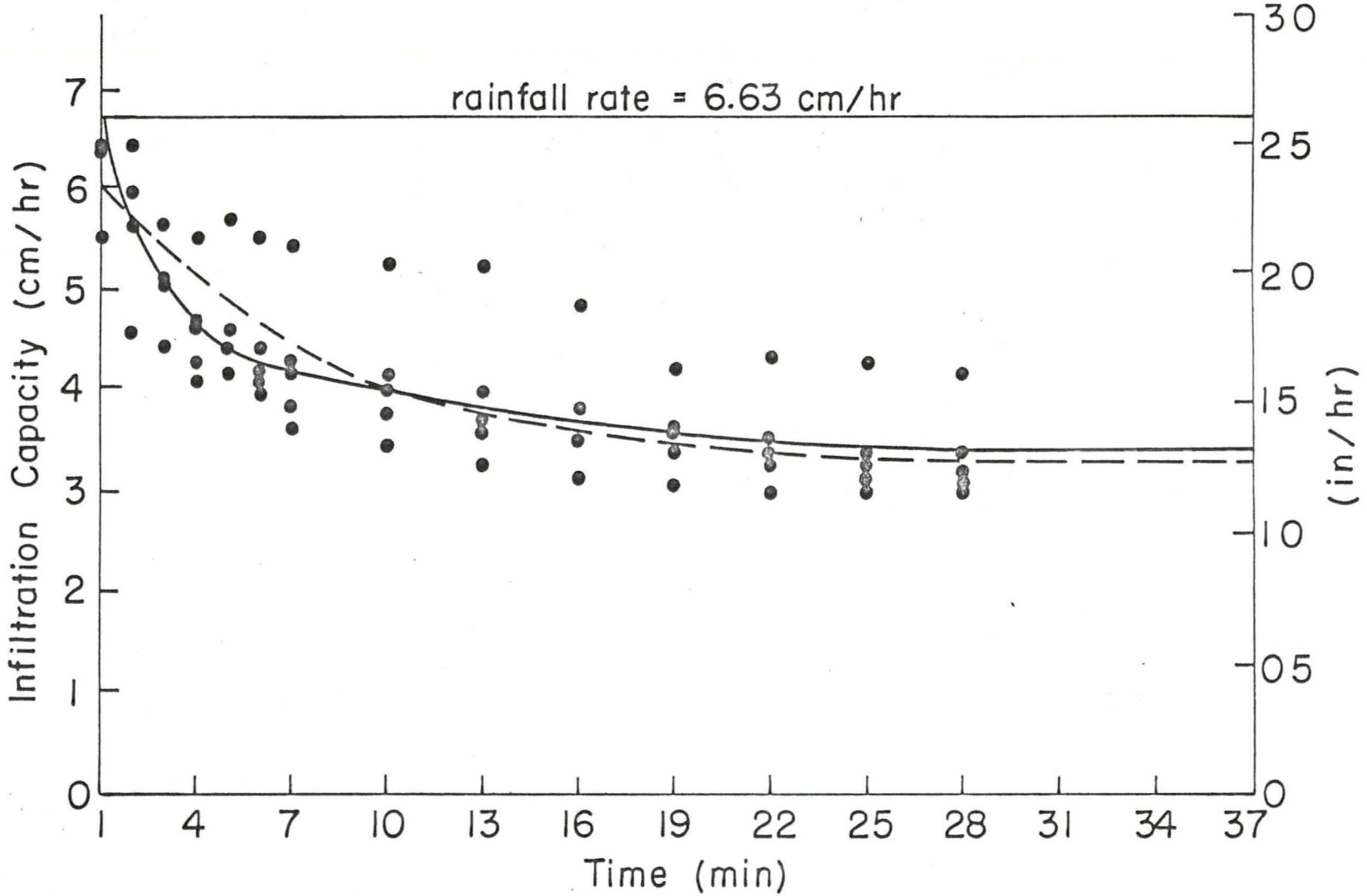


Figure 83. Infiltration curve for the ash at Castle Gate.

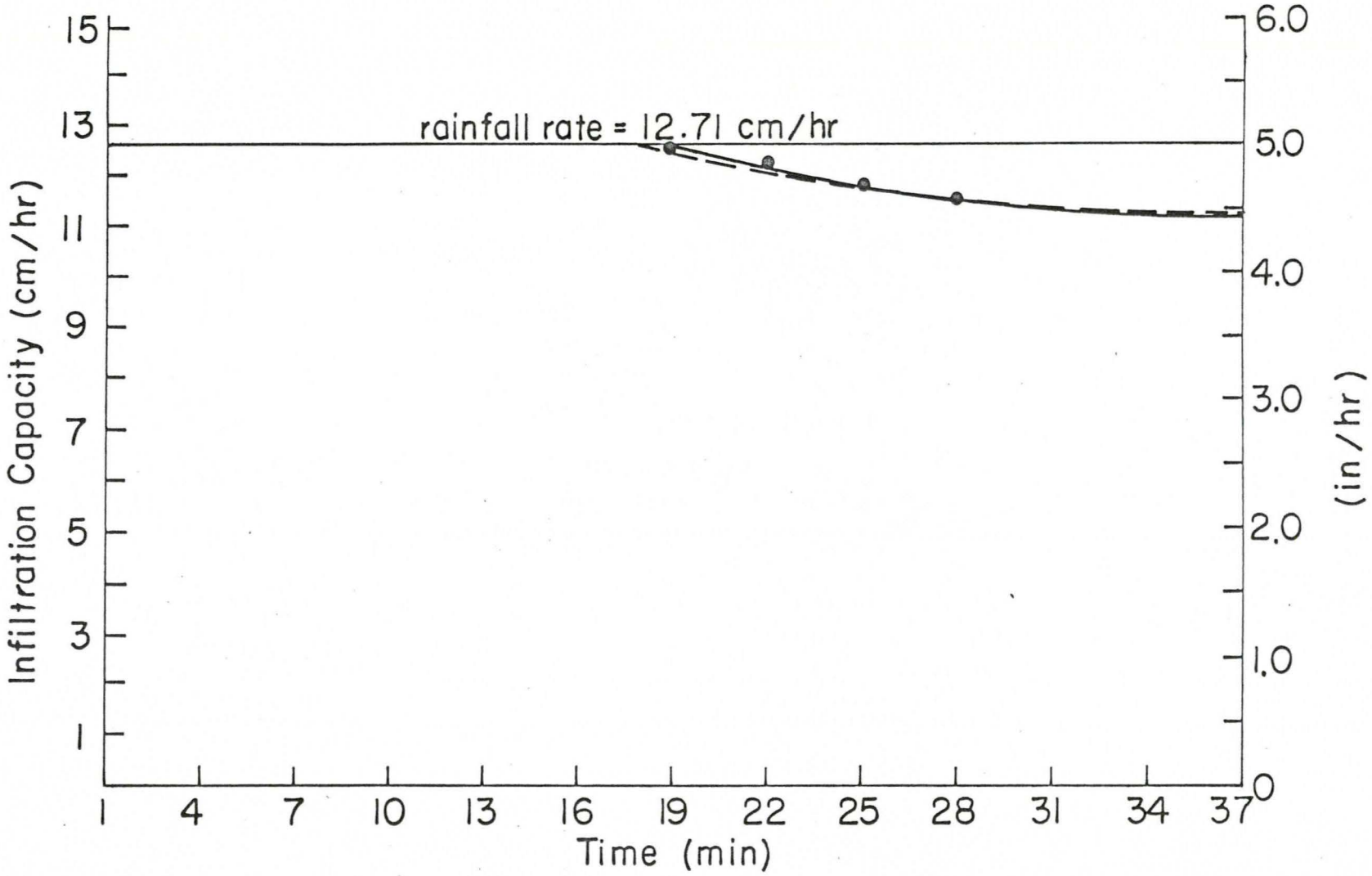


Figure 84. Infiltration curve for the regenerated spoils at Castle Gate.

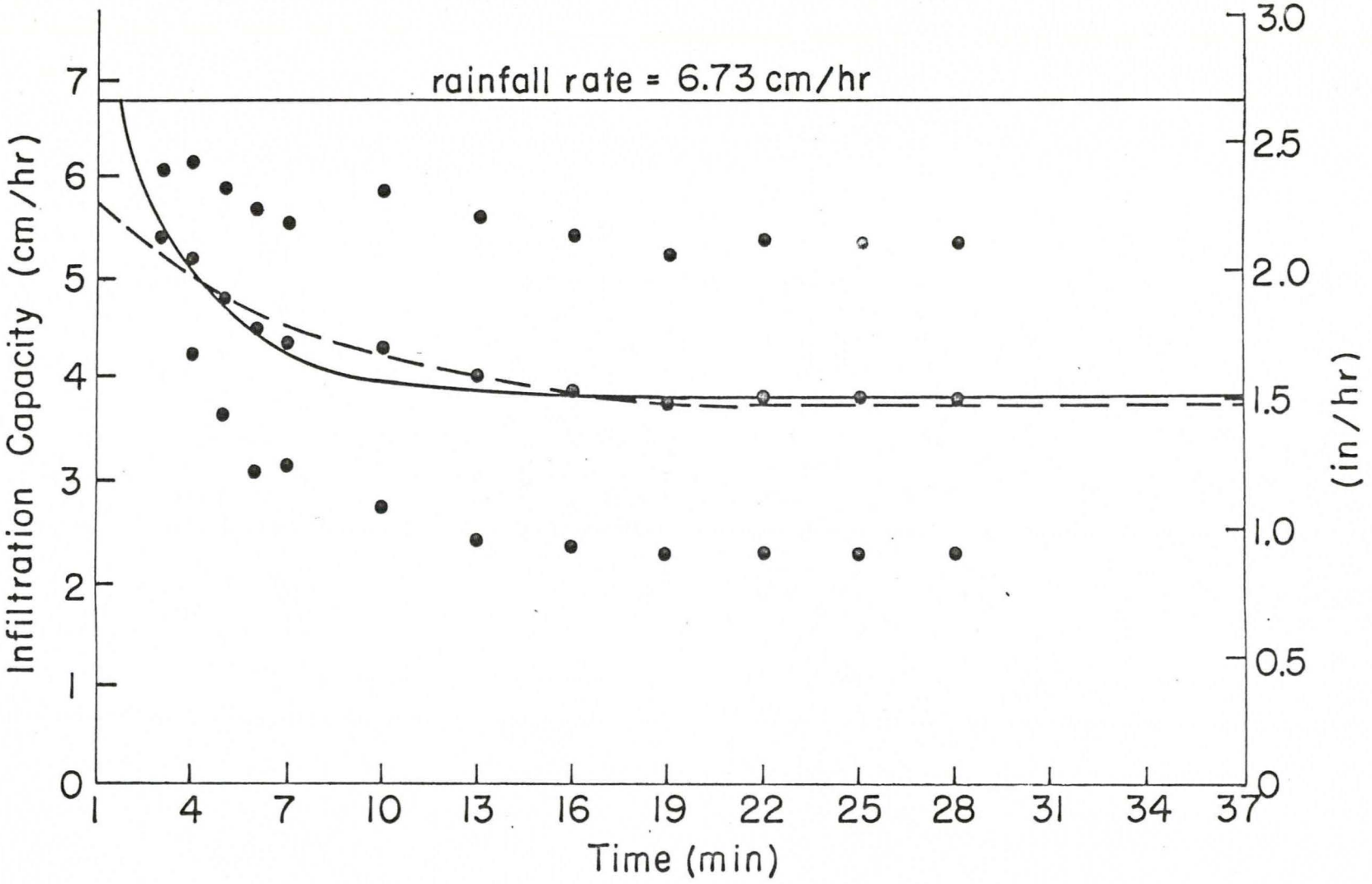


Figure 85. Infiltration curve for the spoils at Castle Gate.

Upon comparison of infiltration rates on seeded versus unseeded spoils (figures 83 and 84), we find the revegetated spoils overwhelmingly more porous. This is most likely due to the fibrous soil textures associated with the vegetated materials.

Potential sediment production shown in table 28 is high on the ash spoils for reasons explained in sub-section T.

W. Vernal

The phosphate strip mine located ten miles north of Vernal is owned by Stauffer Chemical Company. The company mines phosphate from limestones and shales of the Park City Formation. These beds dip south on a hillside facing southwest and are exposed at the surface along the entire length of the hillside. Mine workings are separated into two general areas on this hillside, as shown by the map on figure 86. The two areas are labeled "e-side" and "n-side" on tables 30 and 31.

As overburden rocks are mined from the hillside, spoils are deposited adjacent to and directly down slope from the excavated rocks. A bulldozer pushes the material into large piles that take on the shape of a flat-topped mound (figure 87). Regrading of some of the spoils piles also employs a bulldozer that changes the shape of the deposit making it a long, low, rounded mound.

Samples were taken on regraded and untreated spoils in both sections of the mine. Tables 30 and 31 show selected characteristics for these sites.

Infiltration capacities for each site were reasonably similar. This result shows that surface hydrology can remain constant given spoils piles that have similar geologic derivations and exposure to the same methods of extraction, manipulation, and disposal.

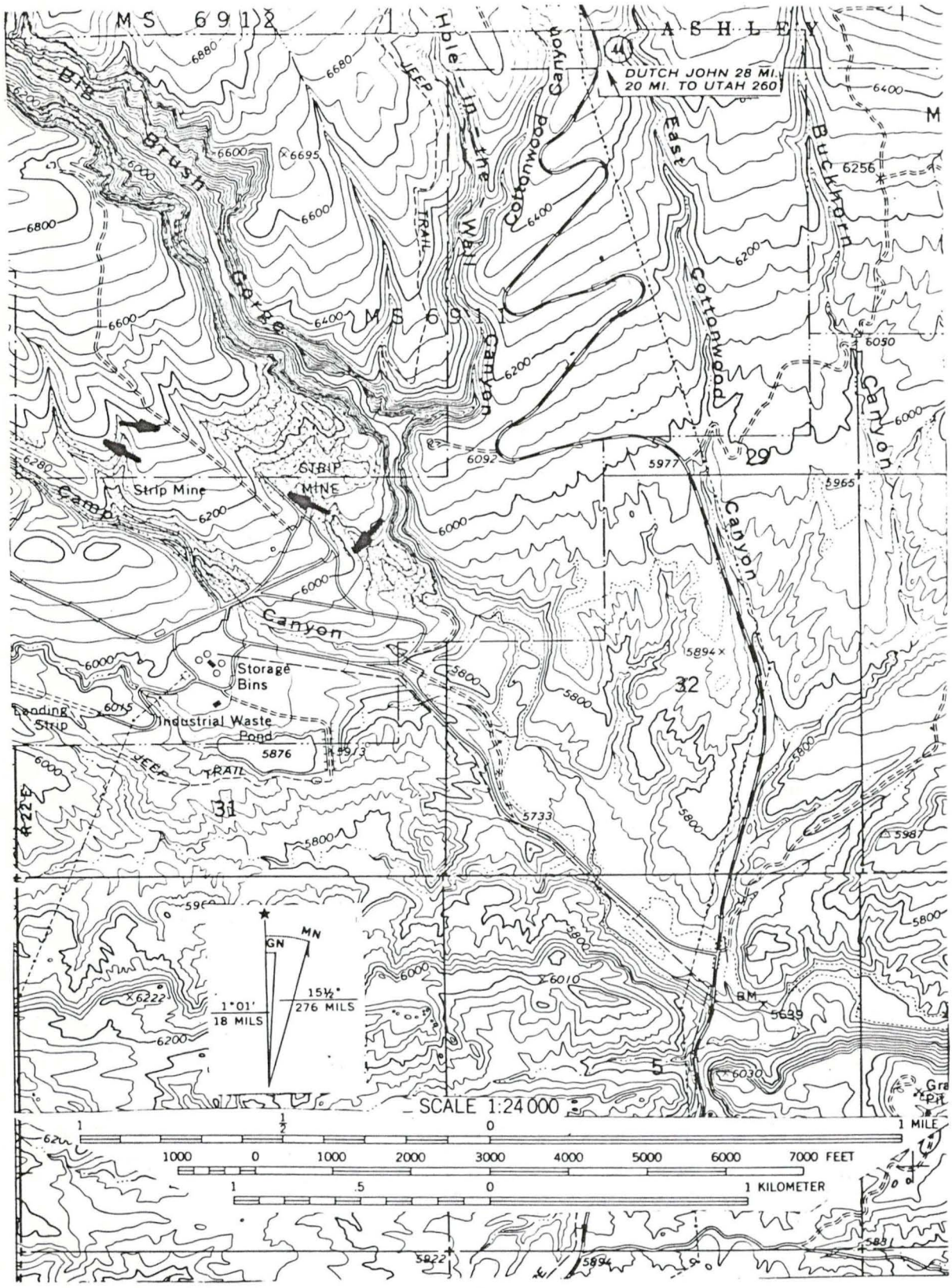


Figure 86. Map of the Stauffer Mine in Brush Creek Canyon, Utah. Reprint, U.S.G.S. topographic 7.5 minute quadrangle.

Figure 87. Stauffer Phosphate Mine: top, distant view of strip mine; bottom, spoils derived from phosphoria formation exposed at left.

Figure 87. (Continued) top, east side of mine showing regraded spoils and eroded surface with brush canyon in the distance; bottom, turbid waters of Brush Creek below mining operation.

Table30 Selected characteristics of site W1, Stauffer, Regraded Spoils.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
10 miles north of Vernal, Utah	6,000	Brush Creek	5

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Park City formation	Sandstone Limestone Shale	8.42

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
60.8	28.7	Utah juniper

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
W(e.side) N.W. (n. side)	19 (e. side) 23 (n. side)	1,000 ft. (e. side) 200 ft. (n. side)	7.7 (e. side)	9 (e. side)

[a] Kinney, 1955. Geology of the Uinta Basin River--Brush Creek area, Duchesne and Uintah Counties, Utah, and field inspection.

[b] U.S. Dept. of Commerce, Weather Bureau, 1960. Data for Vernal, Utah.

[c] U.S.U. Soil, Plant and Water Analysis Laboratory

Table 30 Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
4.3 (e. side)	.35 (e. side)	< .1 (e. side)	20.7 (e. side)

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
61 (e. side)	Clay loam (e. side)	1.85 (e. side) 1.73 (n. side)

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
27 (e. side)	5,944 (e. side) 5,648 (n. side)	7.98 (e. side) 7.65 (n. side)

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
2.62 (e. side) 2.57 (n. side)	6,193 (e. side) 6,489 (n. side)	15.5 (e. side) 14.1 (e. side)

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 30. Continued

Chemical quality of runoff[f]		
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)	
	water applied	runoff
2.5 (e. side)	2.9 (e. side)	3.8 (e. side)
2.2 (n. side)	3.5 (n. side)	4.3 (n. side)

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.6 (e. side)	7.5 (e. side)	100 (e. side)	400 (e. side)
7.6 (n. side)	6.9 (n. side)	1,200 (n. side)	1,300 (n. side)

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

Table 31. Selected characteristics of site W2, Stauffer, unworked spoils.

Location	Elevation (ft)	Utah mining district	Area affected by mining (acres)
10 miles north of Vernal, Utah		Brush Creek	10

Geology[a]		Climate
Outcorping formations	Petrologic identification	Approximate average annual rainfall (in)
Park City Formation	Sandstone Limestone Shale	8.42

Climate[b]		
Approximate average annual maximum temperature	Approximate average annual minimum temperature	Vegetation zone
60.8	28.7	Utah juniper

Aspect	Percent slope	Length of slope	Characteristics of surface materials[c]	
			pH	Salinity (mmhos/cm)
N.W. (e. side) E (n. side)	11 (e. side) 13 (n. side)	250 ft. (e. side) 200 ft. (n. side)	7.6 (e. side)	5.3 (e. side)

[a] Kinney, 1955. Geology of the Uinta Basin River--Brush Creek area, Duchesne and Uintah Counties, Utah, and field inspection.

[b] U.S. Dept. of Commerce, Weather Bureau, 1960. Data for Vernal, Utah.

[c] U.S.U. Soil, Plant and Water Analysis Laboratory

Table 31 Continued

Characteristics of surface materials (cont.)			
Phosphorus (ppm)	Organic carbon (%)	Water soluble Sodium (me/100g)	Sulphate (me/100g)
3.1 (e. side)	47 (e. side)	.7 (e. side)	41.5 (e. side)

Characteristics of surface materials (cont.)		
Material > 2mm diameter (%)	Estimated texture of fines	Bulk density (g/cc)
67 (e. side)	Loam (e. side)	1.73 (e. side) 1.91 (n. side)

Surface hydrology		
Moisture in soil saturation (%)	Total volume infiltration (ml)[d]	Initial rate of infiltration[e] (cm/hr)
--	5,493 (e. side) 6,286 (n. side)	7.04 (e. side) 7.59 (n. side)

Surface hydrology (cont.)		
Final rate of infiltration (cm/hr)	Total volume of runoff (ml)[d]	Total sediment yielded (grams)[d]
2.44 (e. side) 2.79 (n. side)	6,644 (e. side) 5,850 (n. side)	9.8 (e. side) 21.4 (n. side)

[d]For a twenty-eight minute application of rain falling at a rate of 3 inches/hour (infiltrometer studies).

[e]Estimated from the model using Horton's equation.

Table 31 Continued

Chemical quality of runoff[f]		
Concentration of sediment in runoff (g/liter)	Electrical conductivity (MHO x 1)	
	water applied	runoff
1.5 (e. side)	2.9 (e. side)	4.6 (e. side)
3.7 (n. side)	3.5 (n. side)	4.9 (n. side)

Chemical quality of runoff (cont.)			
pH		Salinity (ppm)	
water applied	runoff	water applied	runoff
7.6 (e. side)	7.2 (e. side)	100 (e. side)	1,100 (e. side)
7.6 (n. side)	7.3 (n. side)	1,200 (n.side)	1,600 (n. side)

[f] Electrical conductivity and salinity were determined in the field using a conductivity meter (Yellow Springs Inst. Co.). The Beckman pH Meter was used for determination of pH.

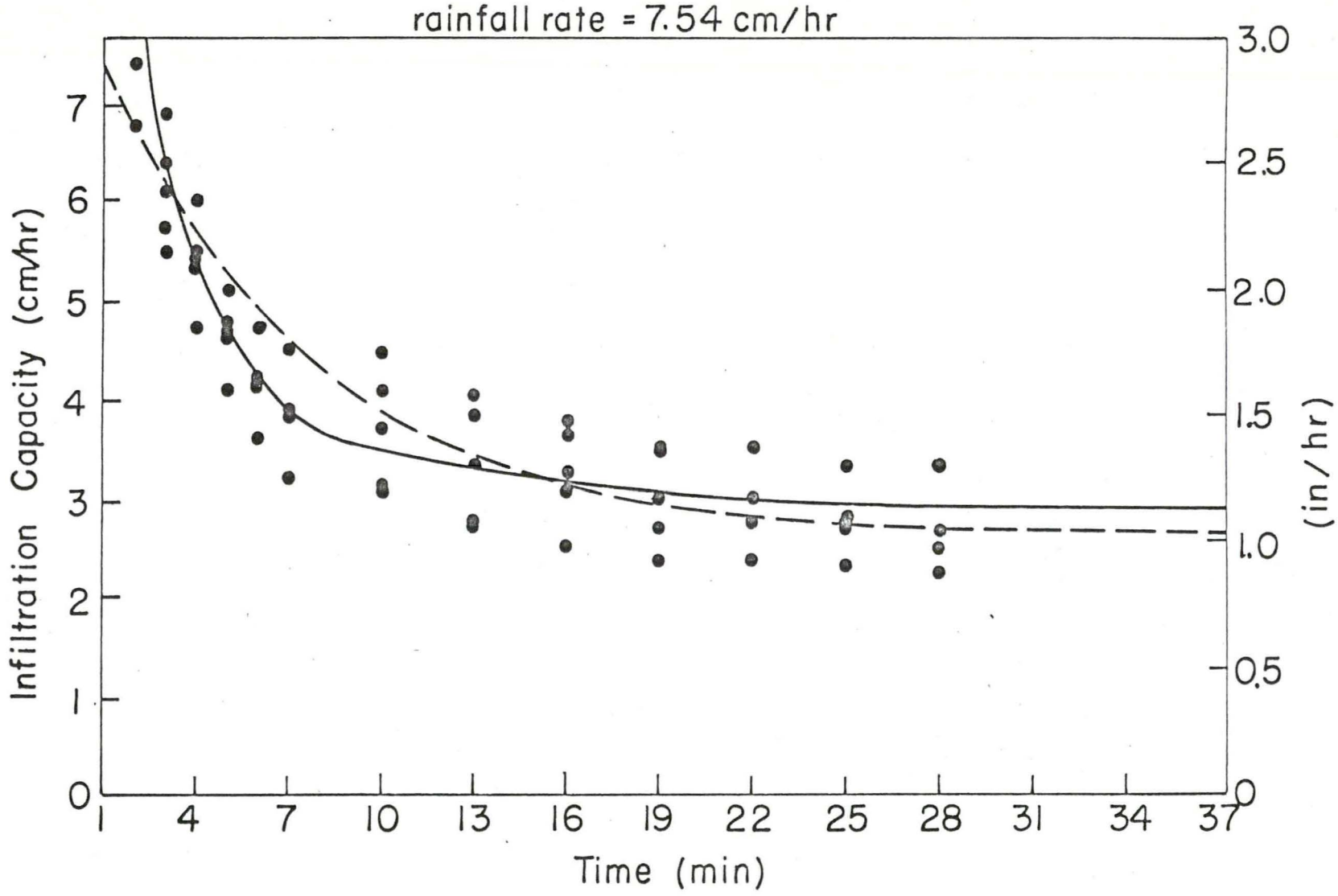


Figure 88. Infiltration curve for the regraded spoils at Stauffer (S. E. side).

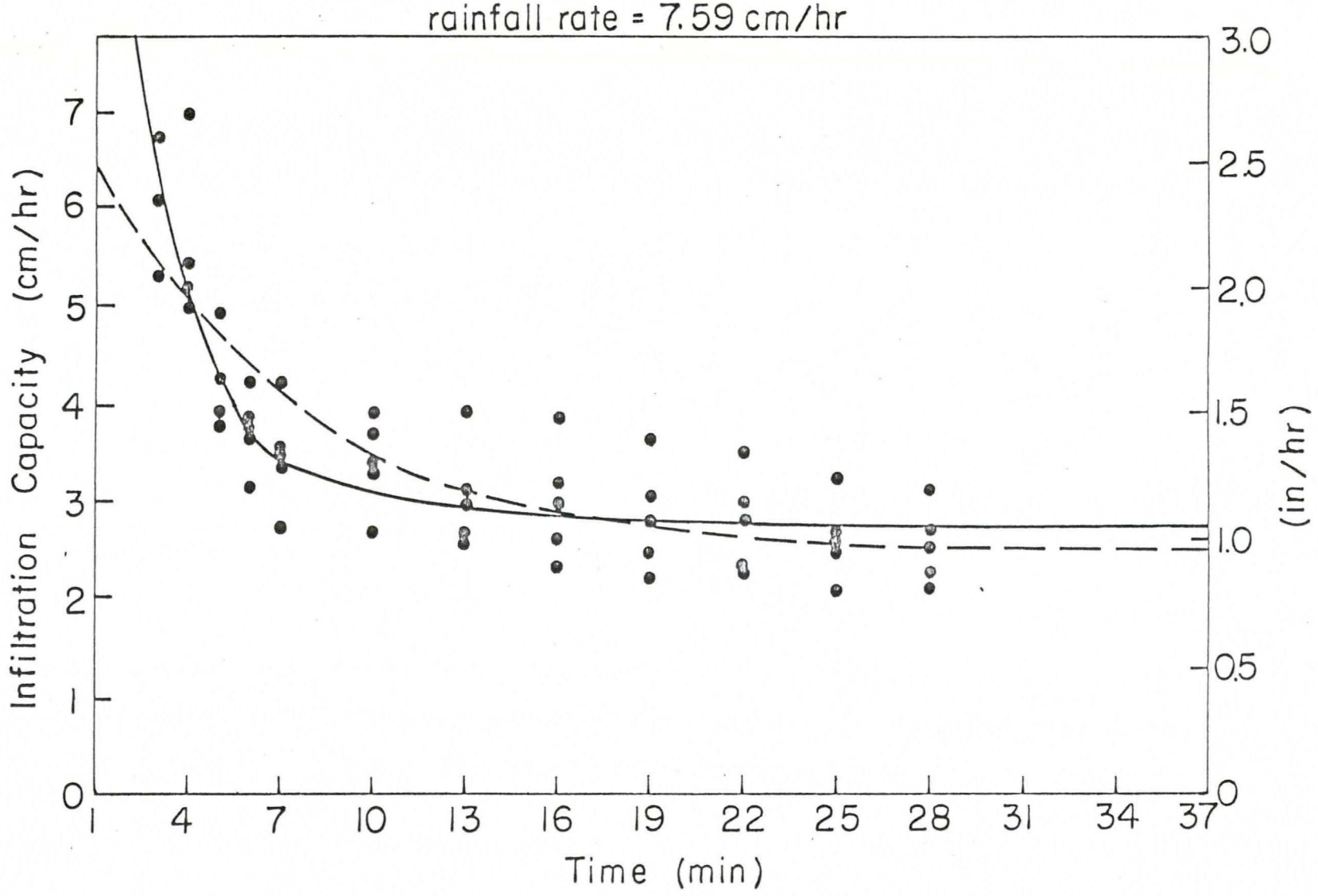


Figure 89. Infiltration curve for the spoils at Stauffer (S.E. side).

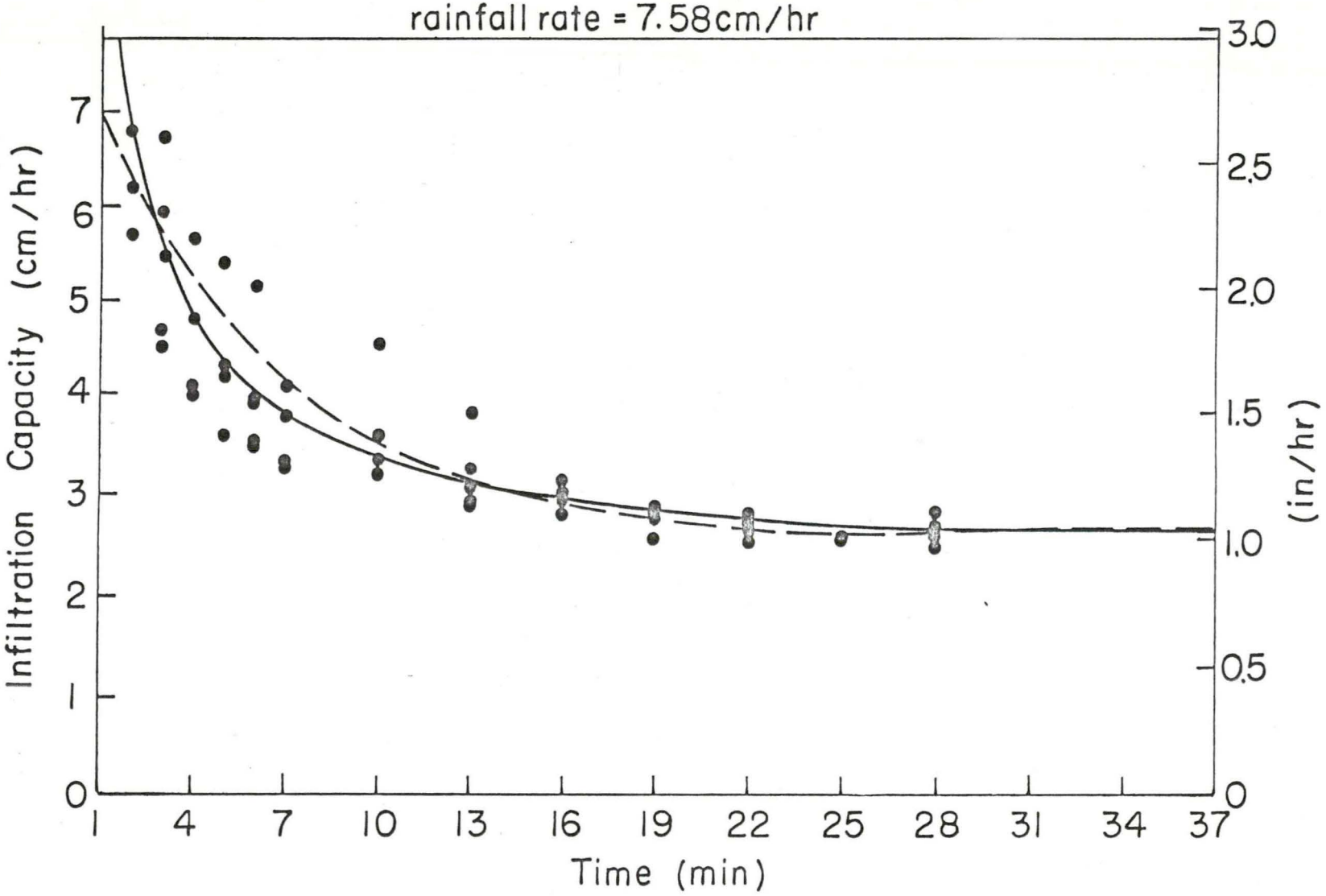


Figure 90. Infiltration curve for the regraded spoils at Stauffer (N.W. side).

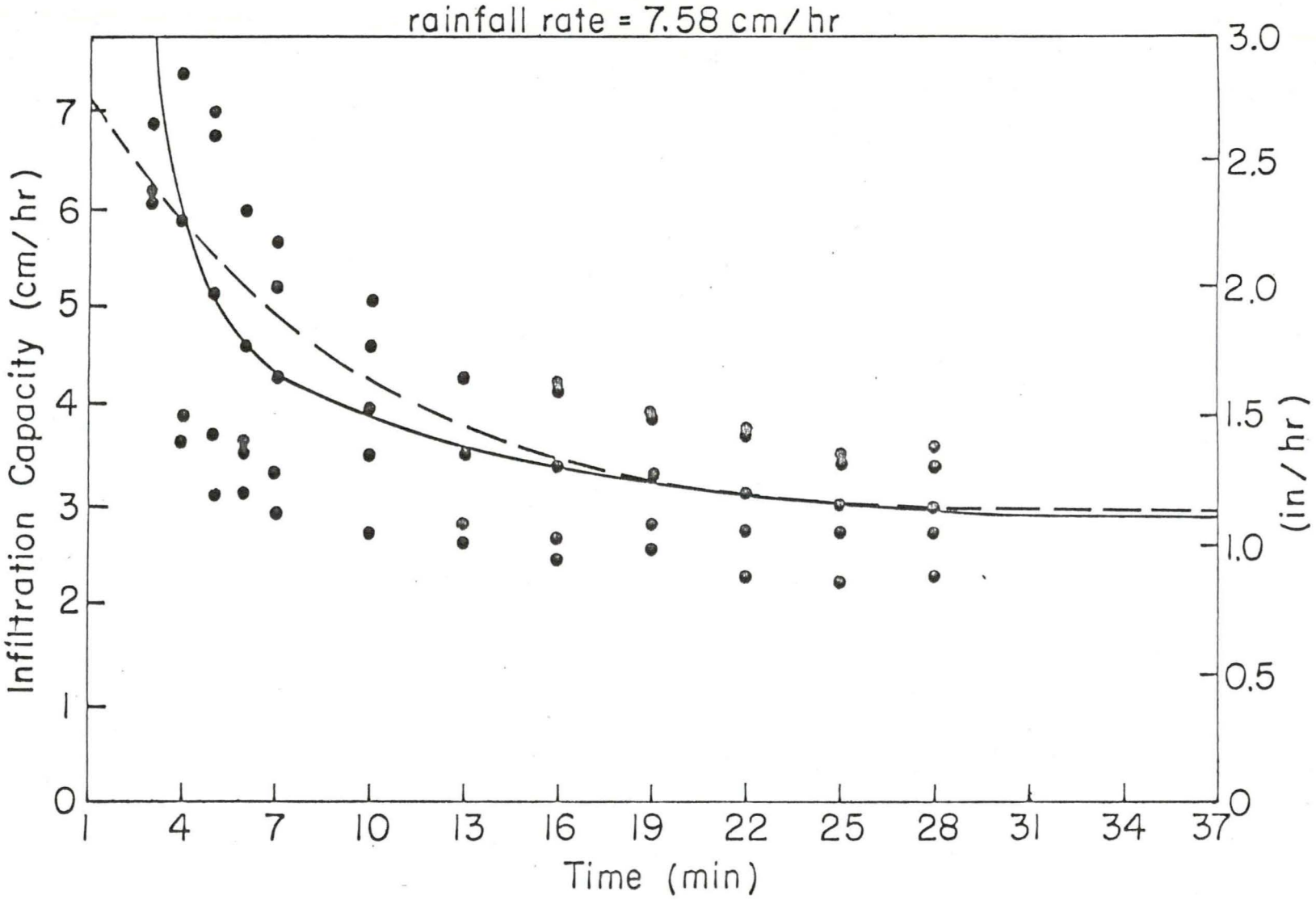


Figure 91. Infiltration curve for the spoils at Stauffer (N.W. side).

Surface conditions on both regraded and untreated spoils were the same (where sampled). They were characterized by bulldozer compaction.

III

METHODS OF ANALYSIS AND CONCLUSIONS

This section describes methods of analysis that will be applied to the data for the purpose of classifying Utah mine spoils and tailings. Some tentative conclusions are made.

Cluster Analysis and Proposed Classification Scheme

The analysis of data obtained for this study will deal primarily with infiltration, erosion, and factors affecting infiltration rates and potential sediment production rates. This will be done for the sole purpose of characterizing mine spoils and tailings in terms of surface hydrologic parameters. Since the characters that describe surface hydrology vary over a large number of spoils and tailings types, it is desirable to classify the spoils and tailings based on similarities between characters (attributes).

According to Sneath (1964), classification is the prerequisite to the detailed study of anything. In such a study, however, the set of data is often too large for the human mind to produce the classification directly. This means that a technique is needed which will classify a large number of objects according to a large number of identifying attributes.

The cluster analysis technique, partly developed by Sneath and Sokal (1973), uses mathematical methods and the aid of the computer to develop a matrix of resemblance between objects being classified and then to produce a phenogram or cluster tree to "map" groups of similar objects.

A natural classification, according to Sokal (1966), uses as many attributes as can be possibly found to describe the objects. The monothetic classification always uses one or a number of chosen attributes to make a classification that will be applicable to purposes pertaining to the chosen attributes. Since this project deals with identifying the objects (spoils and tailings) according to surface hydrology and erosion, a monothetic classification will be used.

Infiltration volumes and rates as well as sediment volumes and production rates will be attributes for this classification. A regression analysis will be used to find other attributes that will be applied to the cluster analysis if they have a high correlation to infiltration or erosion. If such attributes can be found, a multiple regression model will also be derived.

Conclusions:

A few simple graphical comparisons provide tentative results and give a few intuitive feelings about the data. Figure 92 shows that similarities between mine spoils, as far as infiltration is concerned, are related to geologic derivation of the spoils rocks and controls in the environments of extraction and deposition. These conclusions were discussed under sections K, L, and W. Figure 93 seems to substantiate this observation for another type of mining.

The Old Hickory and Bowana mines at Milford, Utah, represent conditions exactly opposite to those described above. Results of the measurements of surface hydrology at these two sites should show considerable dissimilarity. Figure 94 illustrates that they are indeed quite different.

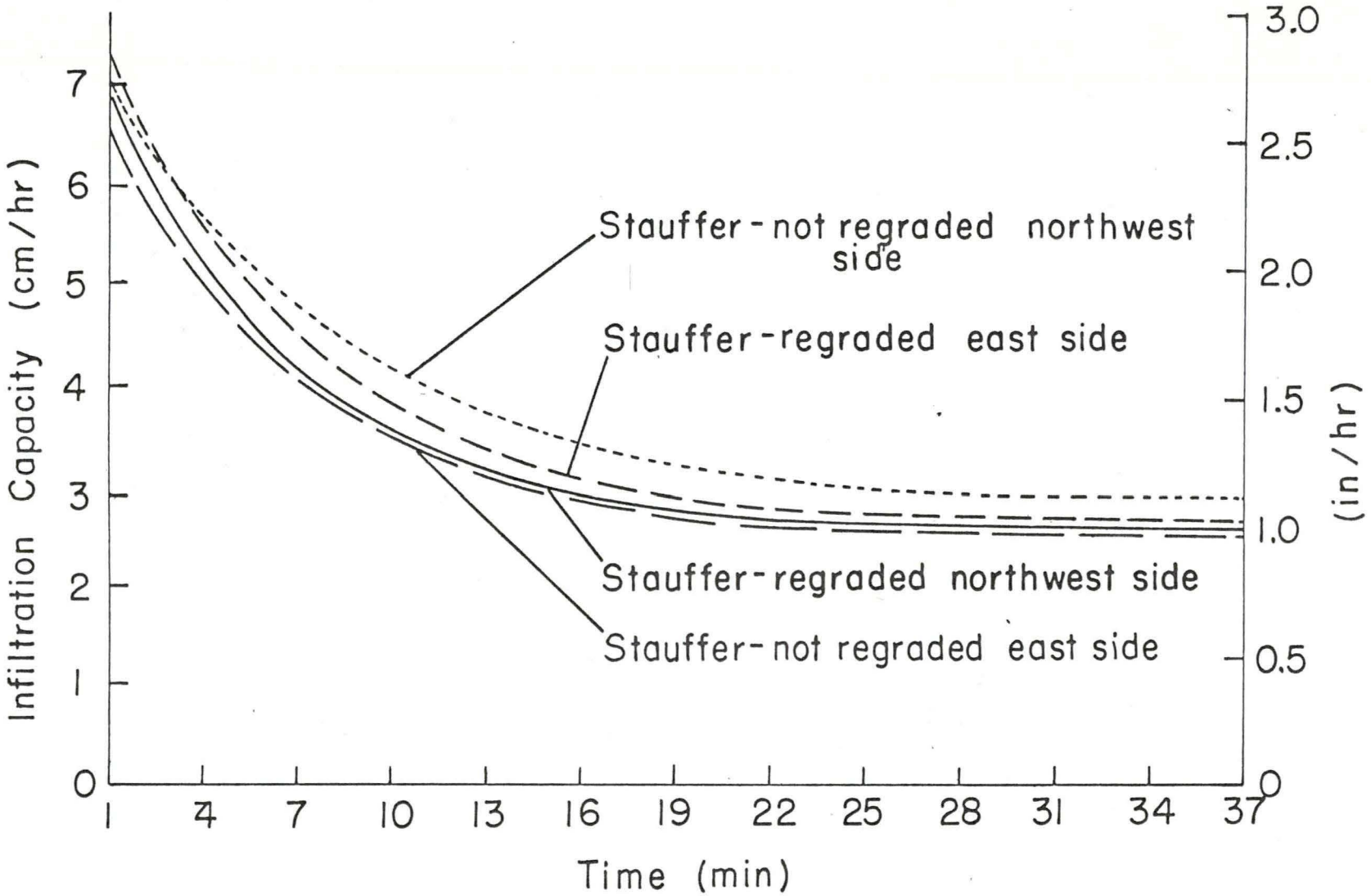


Figure 92. Infiltration curves for Stauffer Mine.

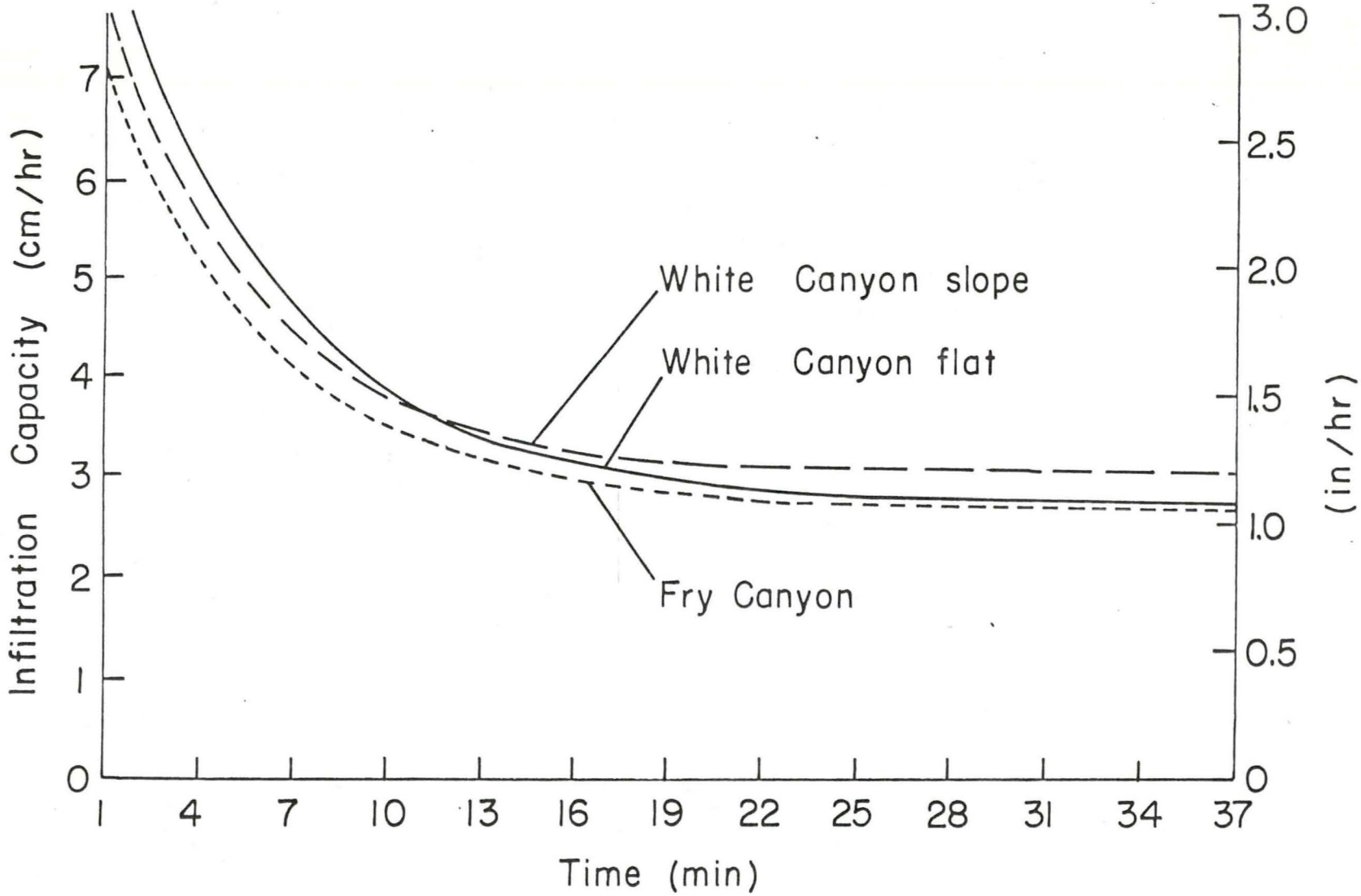


Figure 93. Infiltration curves for two uranium mines near Fry Canyon, Utah.

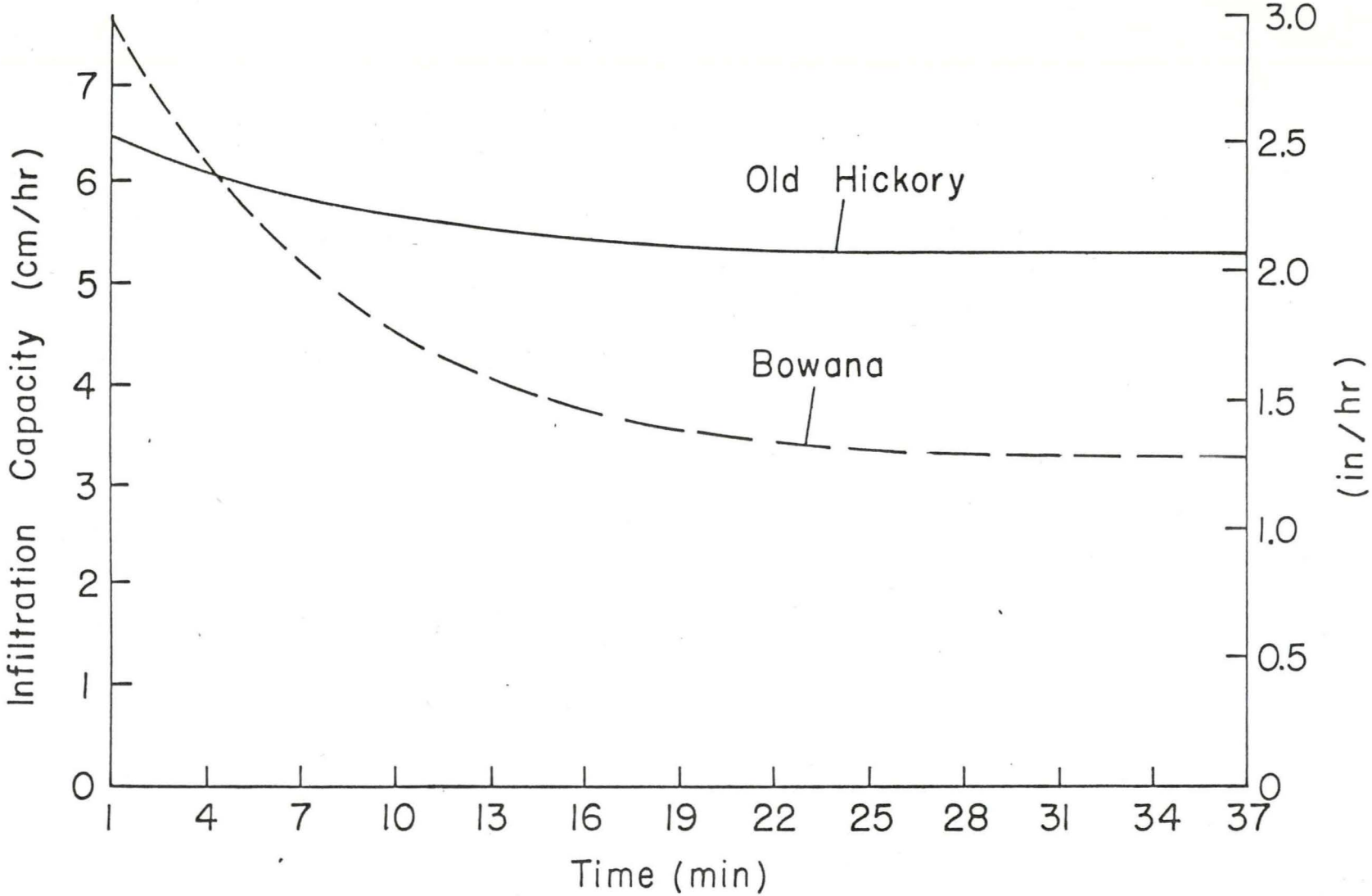


Figure 94. Infiltration curves for two adjacent mines at Milford, Utah.

The effects of compaction have already been discussed several times in the report. Figure 95 shows the decline in infiltration caused by compaction on the spoils flat at Brush Beryllium.

Tailings are believed to be characterized by similar controls. Milling treatments, however, are probably very important since the final product can be changed from the original rock in varying degrees. Figure 96 compares the infiltration curves for two adjacent tailings ponds. Both have the same geologic and treatment derivations. The slight difference between the two curves might be attributed to the complex textural variability on tailings ponds as discussed previously.

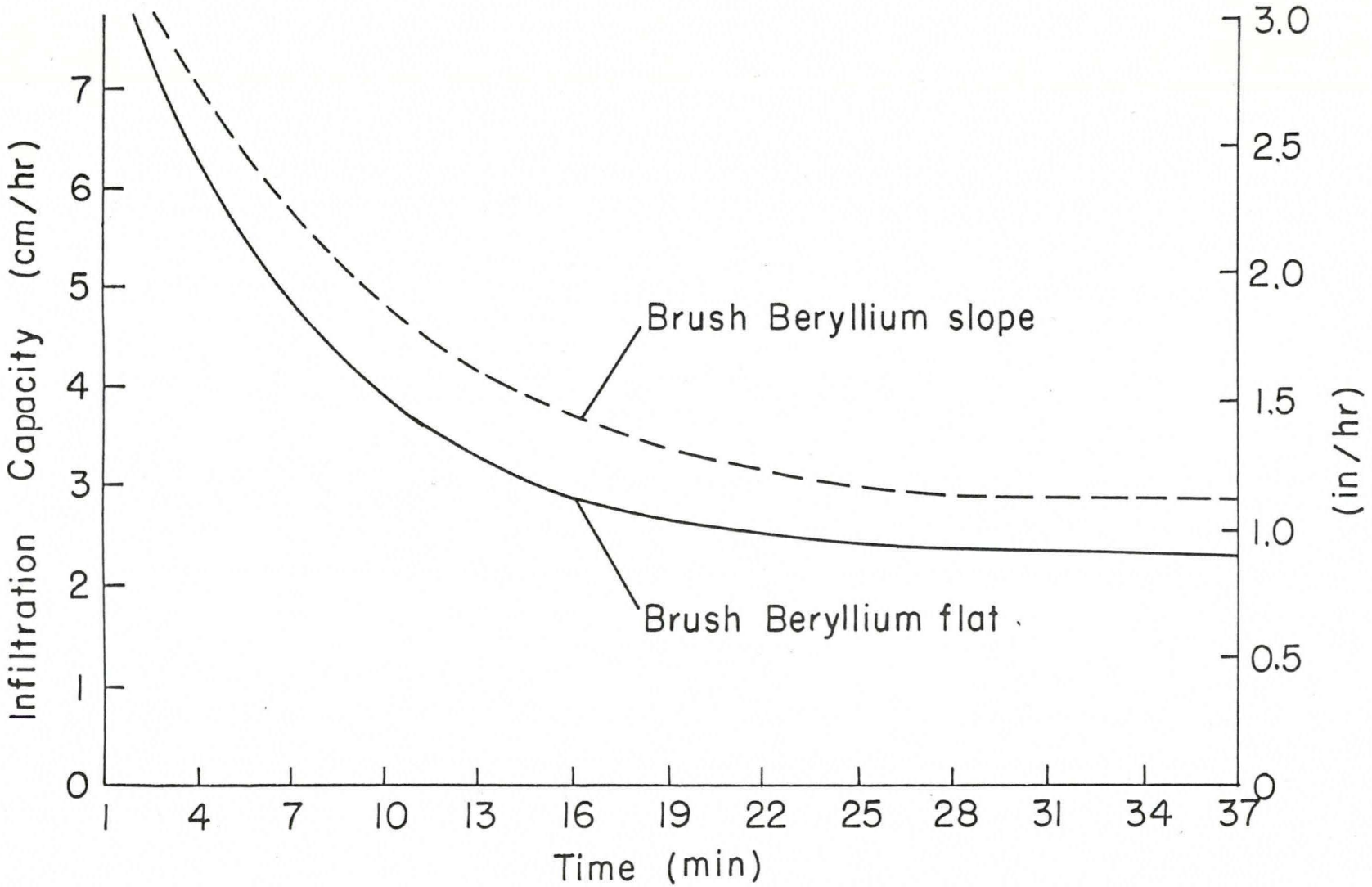


Figure 95. Infiltration curves for Brush Beryllium Mine.

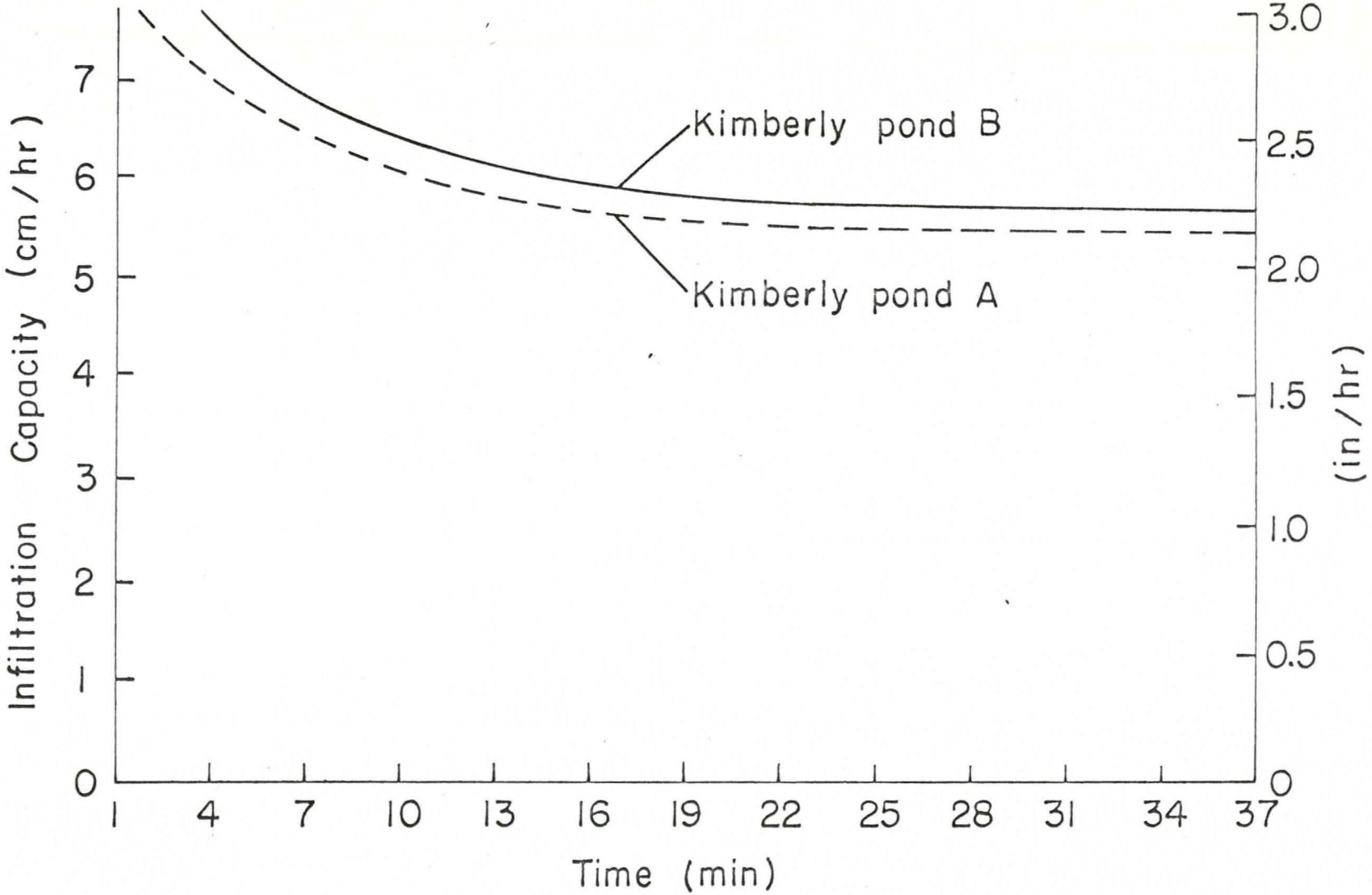
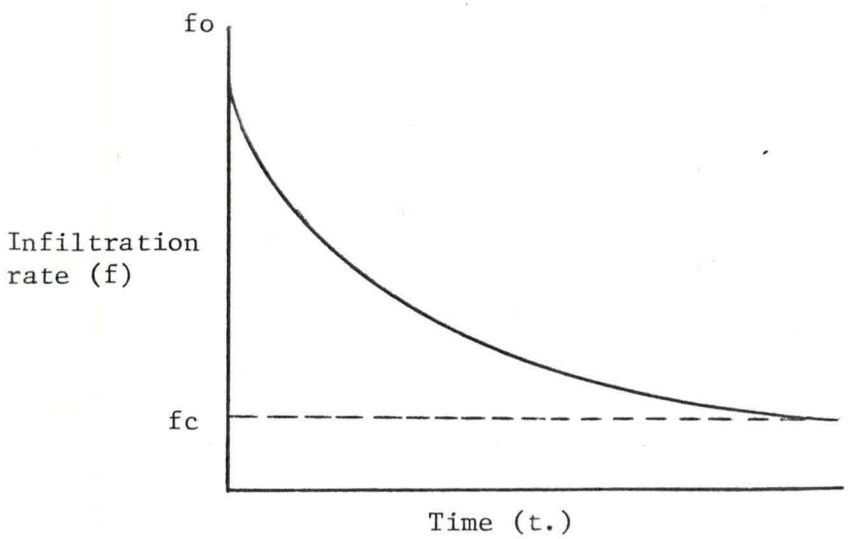


Figure 96. Infiltration curves for two tailings ponds at Kimberly, Utah.

APPENDIX A

The model used to fit infiltration curves to mean values of infiltration at each site uses Horton's equation (1933).

$$f = fc + (fo - fc)e^{-Kt}$$



K is a constant that depends on the conditions of the soil.

A log transformation of the model linearizes the relationship.

$$\ell n(f-fc) = \ell n(fo-fc) + (-Kt)$$

This equation has the form:

$$\hat{y} = bo + b1X$$

Therefore a least squares method was used in solving for the intercept (bo). This leads to a solution for fo. Given fo, the constant K can be solved from either the regression coefficient (bi) or from the following equation:

$$K = \ell n\left(\frac{f-fc}{fo-fc}\right) / t$$

Using the latter method we can generate K from values of observed infiltration rate (f).

Coefficients of determination were computed for each model using the following equation (Neter and Wasserman, 1974):

$$R^2 = \frac{SSTO - SSE}{SSTO}$$

where:

$$SSTO = \Sigma(y_i - \bar{y})^2$$

$$SSE = \Sigma(y_i - \hat{y}_i)^2$$

APPENDIX B

Site	Coefficient of Determination	Correlation Coefficient
Five Mile Pass (slope)	.987	.993
Five Mile Pass (flat)	.966	.983
Lewiston Canyon	.965	.982
Golden Gate	.953	.976
Silver City (slope)	.900	.949
Silver City (flat)	.988	.994
Sunrise Mountain	.945	.972
Spor Mountain	.899	.948
Brush Beryllium (slope)	.984	.992
Brush Beryllium (flat)	.966	.983
Keystone-Wallace (regraded)	.970	.985
Keystone-Wallace (revegetated)	.976	.988
Old Hickory	.957	.978
Bowana	.951	.975
Rattlesnake	.982	.991
Fry Canyon	.952	.976
Happy Jack (flat)	.927	.963
Happy Jack (slope)	.878	.937
Dutchman	.913	.956
Emma (upper)	.945	.972
Emma (parking lot)	.959	.979
Bel Vega	.957	.978
Pacific (tailings)	.935	.967
Pacific (spoils)	.972	.986

APPENDIX B (CONTINUED)

Site	Coefficient of Determination	Correlation Coefficient
Stubbs (slope)	.970	.985
Stubbs (flat)	.963	.981
Mill Creek	.700	.837
Kimberly (pond 1)	.918	.958
Kimberly (pond 2)	.834	.913
Box Creek (slope)	.926	.962
Box Creek (flat)	.948	.974
Hiawatha	.825	.908
Old Frisco (tailings)	.956	.978
Old Frisco (spoils)	.874	.935
Castle Gate (ash)	.946	.973
Castle Gate (revegetated)	.923	.961
Castle Gate (spoils)	.827	.909
Stauffer (regraded, e. side)	.924	.961
Stauffer (spoils, e. side)	.912	.955
Stauffer (regraded, n. side)	.960	.980
Stauffer (spoils, n. side)	.953	.976

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